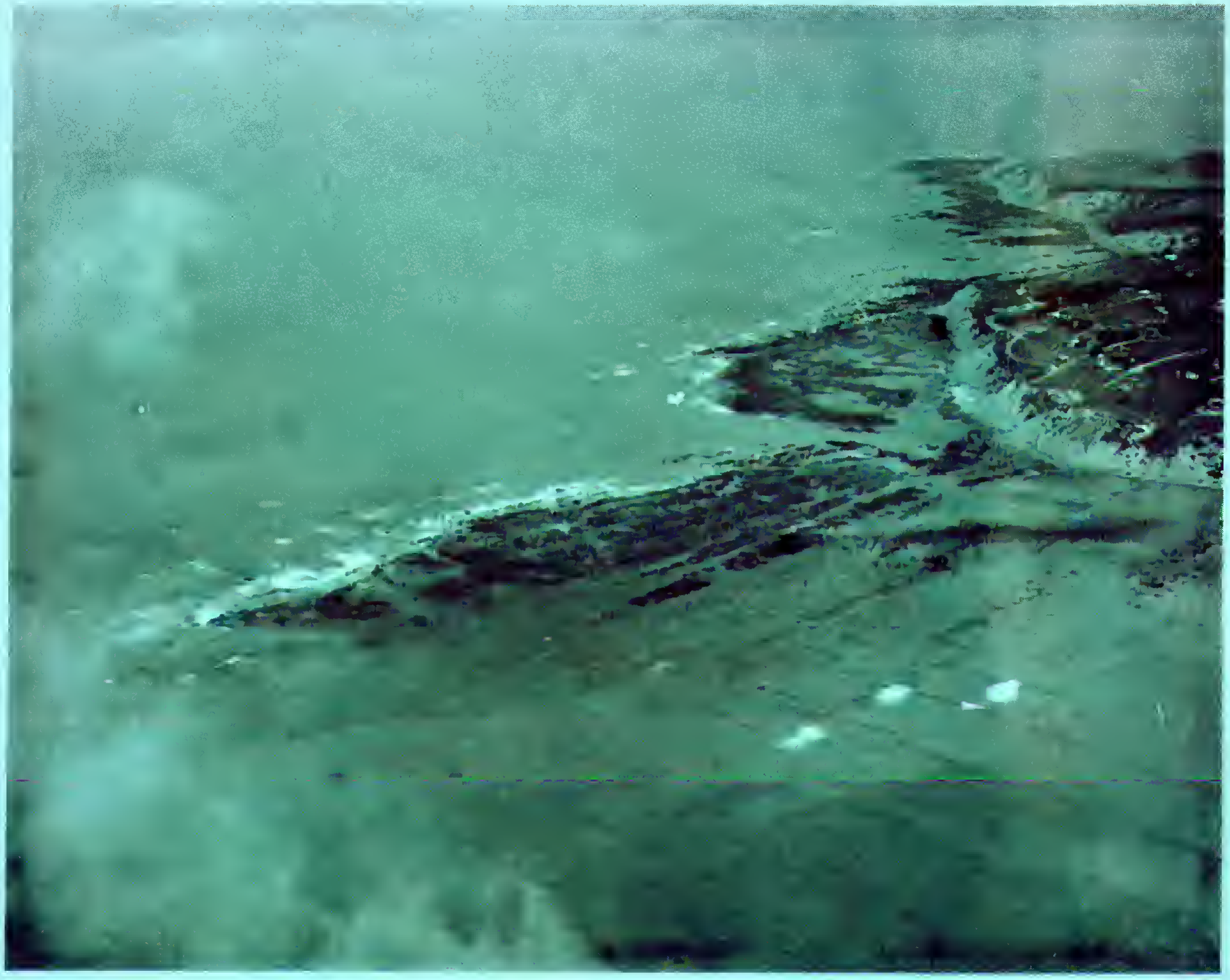

Analysis of the Effects of Field Trips to Duxbury Reef

by

Gordon L. Chan

ANALYSIS OF THE EFFECTS OF PUBLIC AND EDUCATIONAL SCHOOL FIELD TRIPS ON A MARINE ENVIRONMENT, DUXBURY REEF

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January, 1970

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A B S T R A C T

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SCOPE AND METHOD OF STUDY

Public schools, for many years, have instructed their students through various forms of conservation education. Yet a recent writer in Life Magazine, August 1, 1969, asked:

> "How do we develop an ecological conscience in America? Through education, but why haven't we done so? Why aren't children taught to respect all living things?"

The problems of man's destruction of his own planet are being examined and criticized in all media of communcation. The study presented in this research report deals with man's damage to a small portion of the continents--the marine intertidal reefs, specifically Duxbury Reef in Marin County, California. Most urban intertidal reefs have been visited by the general public and the school populations, and as a consequence, remarkable changes in the distribution of marine organisms have been noticed by ecologists. The complaint of conservationists is that these marine habitats are being stripped of their marine life. The general public and school groups have been accused of doing the damage. This report, then, analyzes the actual effects of what man does to a marine reef.

Duxbury Reef in Marin County was chosen as the intertidal urban study site because it is conveniently divided into three natural areas, labeled by the researcher as areas A, B, and C. Area A is easily accessible to visitors, area B is moderately accessible, while area C is rather difficult to visit. The numbers of marine organisms in area C are stable while the numbers in areas A and B are under the greater influence of people. Although the past history of what school groups removed from the reef was tabulated, the heart of the research study was a ten-week period in the summer when the reef receives the most visitors. The first five weeks, May 30 to July 3, 1969, were labled the control period, a time when people did as they pleased on the reef without influence of conservation education. The second five weeks, July 4 through August 7, were designated as the treatment period, a time when conservation education in the form of lectures, tours, signs, and handouts was provided at the reef to all visitors. All activities of the visitors were recorded by observers and five ecological transects were measured in each of the areas A, B, and C to determine if the collecting behavior of people would significantly alter the distribution of marine life. Physical measurements of oxygen, salinity, and temperature were recorded to see if these parameters had any influence on the distribution of marine organisms.

FINDINGS

1. The ranges in oxygen, salinity, and temperature were not significant in affecting the density of marine organisms during the study periods. DDT and other hydrocarbons were concluded to have not affected the density of marine organisms on Duxbury Reef, sections in area C being very stable in their density of marine organisms.

2. The sampling data of past years, 1961-1969, showed a steady increase of school visitors to the reef, along with an increase in the total numbers of marine life collected.

3. Of the 4,278 visitors for the ten-week period, at least 83% came from Marin County and the San Francisco Bay Area.

   The control period showed 2,538 visitors with 59% involved in collecting activities, whereas the treatment period showed 1,740 visitors with 22% involved in collecting activities.

   About 11,000 organisms were collected in the control period and only 900 in the treatment period.

   The average number of organisms collected dropped from 15 animals per collector in the control sample to 4 animals per collector in the treatment sample.

   About 71% of all organisms collected were taken from area A, 25% from B, and 4% from C.

   In the ten-week period, there were more school collectors than general collectors, although the general collectors had the higher percentage of animals collected. For example, in the control period the percentage of animals collected by school visitors was 15.3% while the percentage collected by the general public was 84.7%. The general public gathered far more animals that were edible (clams and snails) which accounted for the large percentage difference; school collectors take small samples of each organism available.

   Overall, the treatment period of conservation education was very effective in reducing the numbers of animals removed from the reef.

4. The base count research on the distribution of marine organisms showed a reduced number of sessile animals due to collecting and a fluctuating population of the mobile animals (snails) as they moved in and out of the meter transects. Overall, during the treatment period of conservation education. there was a stability in the density of marine life, not so for the control period.

5. The use of marine conservation education on school groups was highly effective in the treatment period. The students improved in their behavior of not collecting, replacing animals picked up, turning rocks back over, not tearing up seaweeds, and walking carefully on the reef. The percentage of school visitors who collected decreased from 65.1% in the control period to 19.4% in the treatment period. In the five-week control period, school groups collected an average of 4.5 animals per collector. In the treatment period, with conservation education, the average was reduced to 2.1 animals.

CONCLUSIONS

The major conclusion was that with an increasing reef visitor population, the collecting of marine life will eventually turn the reef habitat into a desolate environment unless conservation and marine refuge policies are enacted. This study clearly demonstrated that marine conservation education does reduce the intensity of collecting in the intertidal region. Therefore, there must be an acceleration of conservation education in our schools, elementary through university, and in the public media to alert people to the fact that their unrestrained collecting habits will incur irreversible damage to reefs and other areas abundant in natural resources.

Specifically, Duxbury Reef should be set aside as a marine reserve with no collecting of animals or other materials, but permitting hook and line fishing from the reef as regulated by the California Department of Fish and Game.

Hopefully, the data of research will initiate a state master plan for reserving many of these outstanding intertidal habitats. There is no protection other than time and abstinence from collecting--and the time is growing short.

ACKNOWLEDGEMENTS

My foremost gratitude is extended to my untiring wife Maxine. She was my constant companion in all my reef wanderings and in the compilation of this research report.

Secondly, I wish to express my deep appreciation to three University of California faculty members: Dr. Lawrence F. Lowery, my graduate advisor, was the chief educational counselor in all the ecological developments of the dissertation project; Dr. Donald M. Hatfield, zoologist, was the guide for my classification of marine organisms; Dr. Pat Wilde, oceanographer, was the scientist advisor for my physical and geological measurements on the reef. I count it a great privilege to have worked under the guidance of these professors.

Thirdly, I am indebted to the students at the Bolinas Marine Station and the staff assistant, Mr. Craig Hansen, for their help--these were my comrades in much of the "manual labor" on the reef.

Lastly, I acknowledge the cooperation given me by Mr. Pierre Joske, Director of Parks and Recreation, County of Marin, and the many other educational and governmental leaders whose constant encouragement made the work so enjoyable.

The friendship of the above associations is my gain.

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THE PROBLEM AND REVIEW OF THE LITERATURE

A. INTRODUCTION

No person reading the current newspapers of this country can escape the deluge of information concerning how man is threatening his own existence--war, pollutions, pesticides, commercial overdevelopment, garbage, etc. On September 18, 1969, C.B.S. television showed an hour-long informational special titled, "The Natural History of Our World: The Time of Man." This show revolved around the centennial theme of the American Museum of Natural History in New York City, "Can Man Survive?" The general public was greeted by an evolutionary show on how man has desecrated himself in war and overpopulation; the show concluded that if man does not take heed of his natural needs of the environment, his days are numbered on this earth.

The chief agency in the United States to cope with man and his environment, the U.S. Department of Interior, used the theme, "Man Is a Threatened Species," to open its recent conservation yearbook.[1] This theme reviews the overpopulation and unbridled self-indulgence by man and his technology on the world environment. The yearbook concluded with the hope that conservation will become a reality in the remaining years--to conserve is to make _wise_ use of the natural resources.

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[1]U.S., Department of Interior, _Conservation Yearbook, 1967 Edition_ (Washington, D.C.: Government Printing Office, 1968).

Biologist Paul Klinge[2] has called for science teachers to stand up and be counted as one such hope in the teaching of relevant science and conservation for present and future generations. In 1965, the Florida State Legislature passed a law <u>requiring</u> the teaching of "conservation of natural resources" in the public schools. Mr. F. T. Christian, Commissioner of Education in the state of Florida, states:

> We're raising a conservation-minded generation . . . this education may well be the key to our survival, as a state, a nation, even a planet.[3]

Even with conservation education, the problem of implementation still remains. Mr. Donald Jackson, writing in the August 1, 1969, issue of Life Magazine, states:

> We have met the enemy, and they are us . . . the one huge dark fact dominating the entire question of land preservation is continued population . . . another dark shadow is the state of public ignorance. How do we develop an ecological conscience in America? Through education, but why haven't we done so? Why aren't children taught to respect all living things?[4]

Many schools have conservation units in their programs, but these are menial in effort, i.e., "save our forest from burning," etc. This research paper will analyze the reasons for and the effect of student and general public pressure on a natural marine habitat; the author hopes that the data and conclusions of this report will illuminate a portion of the realistic goals needed to be taught and utilized in our total school and public educational system.

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[2] Paul Klinge, "In My Opinion," <u>American Biology Teacher</u>, XXXI, No. 4 (1969), Editorial Objectives.

[3] Floyd T. Christian, "Conservation Education Effective in Florida Schools," <u>Florida Conservation News</u>, July, 1969, p. 3.

[4] Donald Jackson, "Threatened America," <u>Life</u>, August 1, 1969, pp. 32-43.

B. THE PROBLEM - The Hands of Man on the Marine Environment

> We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.
>
> --Aldo Leopold

To determine if man is benefiting or destroying his environment, this research paper will present a study of a specific natural habitat--a marine intertidal reef that is close to urban centers. These intertidal reefs are said to be threatened with increasing numbers of public and school visitors. Mr. Ray Chapman, editor of the "Outdoor Californian" newsletter, amply reveals the nature of this research problem:

> The fascinating marine animals that thrive in tide pools along California's 1200 miles of coastlines are in dire danger of being studied to death.[5]

While the general public involvement in collecting and hunting marine animals is significant, school students have been singled out as the group most responsible for depleting marine organisms from the intertidal reef habitats. The background of the collecting motives of students and teachers probably begins with the post-Russian-Sputnik emphasis on science education. This satellite event was the catalyst in structuring the present deluge of students and teachers into our wilderness areas. The major emphasis of this new science education was to remove the students from the classroom atmosphere of book methodology of remembering facts and take them on field trips to the nearby ecological habitats, into the marine intertidal reefs--a clarion call for the "inquiry" approach. The literature revealed the following science education

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[5] Ray Chapman, "Tide Pools Marine Life in Danger," Bay and Delta Yachtsman, January, 1969, pp. 4, 38.

drives:

1. Field trips are unique and exciting

The field trip is perhaps the best teaching method which makes it possible for students to observe and relate natural resources to their own daily living.[6]

Field studies must be given a distinct status above that of the traditional classroom course.[7]

We have lost much of our ability to observe outdoor phenomena. The field trip challenges the power of our observation and man's relationship to his environment.[8]

Curriculum development stresses inquiry, yet this is a glaring omission from the prospective teacher's experience.[9]

2. The sea is an ideal habitat for a "hands on" collection and identification of marine life

Elementary and high school years are none too early for students who are interested in tackling tough problems associated with the ocean . . . an environment with teeming populations of plants and animals.[10]

A marine floating laboratory program for 11,000 students was established . . . This is science practiced in a "hands on" investigation of the media (the sea) constituting seventy per cent of this world.[11]

Field trips require approaches and techniques unfamiliar to the average classroom teacher. The Marine Science Project set up a field trip section . . . the philosophy of field trips has

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[6]M. A. Strobbe, "Utilizing Local Resources in the Teaching of High School Biology," American Biology Teacher, XXIV, No. 1 (1962), 26-29.

[7]Edward F. Pierce, "The Feasibility of Conducting Successful Biological Field Studies," American Biology Teacher, XXIV, No. 1 (1962), 46-49.

[8]J. W. Galbreath, "The Value of a Nature Area in Teaching Biology and Conservation," American Biology Teacher, XXIV, No. 2 (1962), 21-25.

[9]Gladys S. Kleinman, "Trends in Teacher Education," American Biology Teacher, XXIX, No. 8 (1967), 609-612.

[10]Robert S. Bailey, "Marine Science Training Opens Opportunities for Exploration," A & B Science News, VII, No. 1 (1960).

[11]R. B. Linsky, "A Hands On Practice of Science," Orange County, California, 1968. (Mimeographed.)

been to set up discovery-type situations . . . requiring . . . nets, collecting apparatus, preservatives, field test kits, glassware . . . after an hour or more of collecting, measuring, etc., . . .[12]

Marine treasures (animals) are vast . . . man has barely begun to utilize the resources of the seas to meet life's needs.[13]

On unexplored areas . . . collection stations were located and we finally went into the field with seines, formaldehyde, and gallon jars . . . the specimens were brought into the laboratory and contributed to the development of student skills (identification of animals) . . . [14]

The reasons for a seventh grade marine ecology units are:

(1) flora and fauna are readily available for study on "their natural habitat"

(2) collection of this material provides a valuable learning experience

(3) collection of this flora and fauna is relatively inexpensive

(4) many . . . opportunities for projects, etc. . . .

(8) since most students show a great deal of enthusiasm . . . this can be used as a motivational tool for learning[15]

For our BSCS Green version . . . team of students . . . analysis of much collected materials could not be completed in the field during the two-day problem.[16]

The approach (marine biology for elementary schools) stresses the importance of observing living things in relationship to the environment . . . On the first trip, the students . . . collected their specimens, using dip nets, fish traps, digging, prying, sifting, etc., -- and placed them in suitable containers for transportation to the classrooms.[17]

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[12] Will Hon, The Regional Marine Science Project, Carteret County Public Schools, Beaufort, North Carolina, 1969.

[13] T. J. Stopyra, "Sea Pasture," American Biology Teacher, XXVIII, No. 1 (1966), 31-38.

[14] G. W. Murphy, "The River and Its Tributaries: Our Laboratory," American Biology Teacher, XXX, No. 3 (1968), 198-200.

[15] Kleinman, pp. 609-612.

[16] P. J. Hummer, Jr., "Outdoor Classroom--Forest, Stream, and Pond," American Biology Teacher, XXX, No. 3 (1968), 177-180.

[17] Norman Skliar, "Marine Biology in the Elementary School," American Biology Teacher, XXIX, No. 3 (1967), 226-228.

How often have you taught the processes of biological cycles and then failed to take your classes into any natural environment? To learn . . . we collected plankton samples, plants and animals. . . . Each student was required to make a scientific collection, to be collected, mounted, and identified in the approved manner. . . . I (the teacher) had a feeling of accomplishment and now am looking forward to this coming summer and another course in field biology. Why don't you offer such a course too?[18]

Students should make field trips to the seashore whenever possible to study and make collections. Several low-priced pocket field guides are available to assist in identification.[19]

As any instructor knows, no student will be more interested than the one who has seen and collected animals and plants he studies. Equipment necessary for such collecting expeditions, besides warm clothes, includes: tubs, pans, buckets, jars, etc. To enhance the value of either collecting trips or tours, groups should be instructed to take notes. The instructor himself will not only get the pleasure of collecting trips and tours but may get the joy of knowing his efforts were a definite aid in the career selection of his students.[20]

Our shores teem with wealth of fascinating marine life. To obtain the greatest number of species in the shortest time, concentrate your efforts at . . . Duxbury Reef.[21]

In the foregoing excerpts, the key phrases are:

a. Take field trips--the seashore is a great spot.

b. Bring buckets, nets, etc. to collect marine life.

c. Identify the species (classification) back at the laboratory.

d. As a teacher, you will see joy and learning in your students.

Since most of these choice epitaphs come from "teachers' magazines", these no doubt encouraged thousands of teachers and pupils to

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[18]H. G. Liebherr, "Field Biology in the High School Program," American Biology Teacher, XXIII, No. 5 (1961), 285-287.

[19]E. Winslow and A. B. Bigler, "A New Perspective on Recreational Use of the Ocean," Undersea Technology, July, 1969, pp. 51-55.

[20]J. M. Youngpeter, "Field Trips," American Biology Teacher, XXIII, No. 5 (1961), 273-275.

[21]Marin Times, "Our Shores Teem with Wealth of Fascinating Marine Life," San Rafael Independent Journal, April 2, 1961, pp. M10-M11.

rush to the seashores to collect marine organisms--all as a part of their new science--the inquiry approach. In fact, some teachers may even justify their collecting under the banner of conservation! The following comes from a well-known southern California teacher:

> The marine biology course . . . was started by teacher interest . . . consists of a four-hour block program.
>
> Conservation is stressed at all times during the program. Certain ground rules are laid down for field trips: collecting is limited to samples only, and only if the specimen is not already in the teaching collection. . . .
>
> The specimens we collect during the summer serve as a resource collection and are used by the science department, elementary schools, and colleges and universities during the regular school year.
>
> Time allocation is . . . flexible . . . especially on days following field trips, when sorting, keying, and preservation of specimens must be done. Students are expected to learn both the common and scientific names of the flora and fauna they investigate. All specimens must be correctly identified before they are catalogued and placed in the teaching collection.[22]

Notice the justification of collection in the above reference: (1) conservation, (2) teaching collection, (3) use of the collection by the elementary schools, colleges and universities. Educational field trip collecting excursions seem to be patterned in a chain-like sequence. In higher education, university and college instructors take their students on collection trips. High school teachers and elementary students follow suit to imitate their big brothers at the universities. Each, in turn, probably utters that his collecting reasons are more justified than that of others, and all probably use "scientific inquiry" as the basis of their collection. In the following research, the shape of the total numbers of educational

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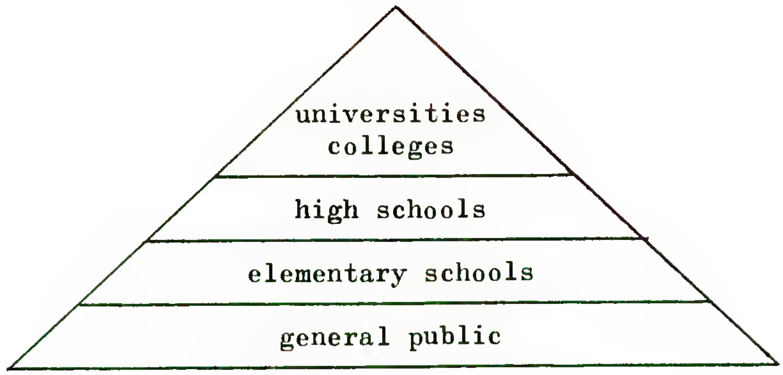
[22] R. B. Linsky, "Marine Biology--a Summer Enrichment Course," The Science Teacher, XXXIV, No. 6 (1967), Reprint, pp. 1-2.

collectors is hypothesized to appear as a pyramid:



When the general public sees the educational institutions ravage a natural habitat or a marine reef, their similar actions will also appear to be justified.

Adding up the total collectors and analyzing what they remove from a marine reef will be one important data coming from this paper.

3. <u>The still small voice of concerned conservationists</u>

The literature does not reveal many individuals who feel that removing marine wildlife constitutes an environmental hazard. Most writings today reflect man's pollution, pesticide, oil, and technological developments as endangering marine environments. The American Museum of Natural History television show on September 18, 1969, stated that of all the living animals in history, two-thirds are now extinct, and the ratio may soon involve man. The following represents the still small voice of conservationists concerned over the collecting habits of man on a marine environment:

> A new dimension in teaching is needed . . . in protesting and understanding and teaching the virtue of conserving biological life, rather than the view that it is all so much raw material for human consumption . . . the burden of responsibility is on the biology teacher. . . .[23]

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[23]William Drake, "Natural Areas," <u>American Biology Teacher</u>, XXIV, No. 1 (1962), 14-17.

In-service workshop (a solution) . . . to stress the true application of scientific principles of conservation of wildlife.[24]

The fascinating marine animals that thrive in the tidepools along California's 1200 miles of coastline are in dire danger of being studied to death.[25]

Collecting is a popular hobby, prying up and overturning rock is deadly. A southern California junior college class used copper sulfate drug to collect specimens, thus killing many species, including hundreds of starfish.[26]

We are going through a period of biological evolution unmatched in the history of the earth. Whole environments are being wiped out, species which have evolved over billions of years are being brought to the threshold of extinction . . . biology teachers who have been given the responsibilities for developing courses and curricula to give their students an understanding of the science of life . . . in this they have failed.[27]

<u>The lack of field experience available to students is the direct result of neglect in teacher preparation at teacher's training institutions.</u> Students and teachers alike must be made aware of the dangers of indiscriminate collecting. Time after time we have learned, the hard way, that the approach to conservation and management of our environment must be an ecological one. If we emphasize this concept in our preparation of teachers, we would find them, in turn, making the same point with their students.[28]

The effects of conservation practice touch the lives of all human beings . . . it should touch our young people, for in them lies the hope for the intelligent use of our natural resources.[29]

In many cases, too many teachers are passive so far as

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[24] A. Henderson, Jr., and Robert Corradino, "An Experimental Workshop in Biology for Elementary Teachers," <u>American Biology Teacher</u>, XXIV, No. 5 (1962).

[25] Chapman, pp. 4, 38.

[26] Wesley Marx, "Science and the Rocky Shore," <u>Sea Frontiers</u>, XIV, No. 1 (1968), 50-60.

[27] M. J. Brennan, "Biology Out-of-Doors in the Elementary School," <u>American Biology Teacher</u>, XXIX, No. 3 (1967), 207-210.

[28] K. L. Greene, "Natural Environment Awareness, Part II: Including Field Trips," <u>American Biology Teacher</u>, XXX, No. 7 (1968), 552.-556.

[29] James E. Jenkins, "A Study Unit for Outdoor Education and Conservation," <u>American Biology Teacher</u>, XXIV, No. 1 (1962), 30-32.

> conservation is concerned. . . . I am afraid that a great number of teachers know what others should do and even what they should do, but few of them are doing it. The responsibility of teachers in conservation deserves more attention. . . .[30]

C. IMPLICATIONS OF THE PROBLEM

The before-mentioned references illustrate the problem: that is, the school populations, along with the general public, are "collecting" organisms faster than the natural rate of reproduction of these organisms. With the expanding populations, any environment is threatened--alpine, chaparral, desert, and marine. The focus of this research is on the marine habitat, the intertidal zone, with the special research study on Duxbury Reef of the Bolinas headland, Marin County, California.

Marine intertidal reefs along California are being deluged with people. Authorities have accused the educational students of being the culprit in the depletion of marine life on the reef. The general public which visits these same areas is also being incriminated. Exactly how much damage do these people inflict on marine reefs?

No one has the complete answer to the damage done by collecting hands at the seashores. I posed this question at the International Symposium of Coastal Lagoons in Mexico City in November of 1967, and of the 400 delegates of international scientists present, not one knew of any papers delineating the problem. Dr. Robert F. Dill, oceanographer and Chairman of the California Advisory Board on Underwater Parks and Reserves, at a September 16, 1969 meeting on the Salt Point Underwater

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[30] John W. Klotz, "Natural Areas as a Community Resource," American Biology Teacher, XXIV, No. 1 (1962), 18-20.

Park, was asked if he or his board knew just how much damage is being done to marine reefs by visitors. Dr. Dill replied that he knew of no studies that would present any figures. Marine biologist Charles H. Turner of the California State Department of Fish and Game stated at the same meeting that no such quantitative studies have been recorded. In my search of the literature throughout the California state institutions of higher learning, in national publications, and through the Educational Research Information Center (ERIC) clearing house of educational information, I did not find a single report of study on the behavior of visitors on marine reefs, nor on the species being collected. The major importance of this research study is to describe the unknowns in this marine problem so that intelligent recognition and decisions may be made for the wise use of our marine resources.

1. An example of the implications of the problem

A startling and parallel implication of man destroying a marine environment through collecting is currently being studied in the tropical Pacific. The problem involves a very spiny starfish, *Acanthaster planci*, the Crown of Thorns starfish. This starfish, armored with poisonous spines, feeds on the living coral polyps—the marine animal that builds coral reefs—devouring the coral polyps until a very porous white skeleton remains. One report on this coral-destroying starfish[31] on the Great Barrier Reef of Australia has recently appeared in the National Geographic Magazine (October, 1969). The damaging effects of this event were described in the article as:

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[31] C. J. Woerner, "The Acanthaster Planci," American Society for Oceanographer, August, 1969, p. 4.

a. Effects

1. The dead coral skeletons are crumbling.

2. A neurotoxic algal slime is infesting the coral remains. Fish eating this algae picks up the neurotoxic algae, and when man catches the fish and eats it, a hallucinogenic illness to death occurs, an incident which has been observed among reef natives.

3. The coral reef which abounds with tropical fish provides a livelihood for thousands of islanders and together with tourist attraction the reef is an outstanding natural resource for the world to preserve.

In the reef areas of Guam and the Great Barrier Reef of Australia, there are more than 3000 Crown of Thorn starfish per acre and they are destroying the coral fringe at the rate of half a mile a month. Scientists attribute this infestation to two major causes.

b. Causes

1. The giant trumpet snail, Charonia tritonis, immune to the poisonous spines of the starfish, feeds on this coral predator. Australian scientists estimate that this trumpet snail, highly prized by shell collectors, has been professionally collected at a rate of 10,000 per year for the last fifteen to twenty years. The price of this shell has ranged from $3.00 to $35.00 per shell! Where the starfish abounds, no trumpet snails are found and the observation is vice versa on the coral reefs. Thus man, by removing the predator of the starfish for dollar profit, is in turn destroying his own major economic attraction, the coral reef.

2. On Guam, scientists attribute the shallow water construction --blasting, dredging, etc.,--of the coral reef as the primary cause of the starfish infestation. The destruction of the coral prevents the living polyps of the coral from feeding on starfish planktonic larval, thus accelerating the population growth of the Acanthaster planci. Some predict that this starfish may spread throughout the Pacific, even to California!

Unless the coral reefs are preserved through control of this starfish, the destruction of the living corals will be a disaster for Oceania. Upsetting the balance of nature by removal of the Triton trumpet shell is a hideous event of man.

In the course of history we can easily read where man's invasion has literally obliterated species after species of wildlife by all the past and present contaminants of man on his planet--oil, pollution, pesticides, detrimental commercial development, radioactivity, garbage, etc. The greatest damage to earth may be the result of the collecting hands of man--that of destroying one of the seven natural wonders of this earth, the Great Barrier Reef of Australia and the coral reefs of Micronesia-Melanesia Islands! Has the balance of nature already been similarly upset and become irreversible on some of our California intertidal marine reefs? Again, this research paper will illustrate the damage done by visitors to one of these seashore habitats.

The generation of today must be concerned with the environment for future generations. In recent perspective on the recreational use of the oceans,[32] it was predicted that seventy to eighty per cent of the U.S. population will live in the thirty-one coastal states by 1980. This will mean close to 100 million people seeking the ocean coastline for some part of their recreation or activity. In 1968, $14 billion were spent on ocean oriented recreation and by 1980, the forecast predicts up to $28.6 billion dollars will be the amount spent in ocean activities. This impending population pressure on the marine environment will cause future dilemmas unless the current marine leaders understand the growing problems and move now to enact constructive measures.

In a recent issue of the San Francisco Chronicle, conservation

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[32]Charles D. Wise, "Dear Student: Are You Interested in Oceanography?" American Biology Teacher, XXI, No. 8 (1959), 341-346.

writer Harold Gilliam[33] described the many agencies in the San Francisco Bay Area that are actively concerned with the preservation of the environment. These are listed with their major interests:

Sierra Club--founded by John Muir in 1892 to halt deterioration of natural resources
San Francisco Bay Conservation and Development Commissions (BCDC)--to control Bay development
Northern California Committee for Environmental Information--pollution, population
Ecology Action--smog
Ecology Center--courses on ecology
San Francisco State and San Jose State Colleges have human ecology programs
University of California Extension has twelve new courses on natural environment
College of Marin and College of San Mateo have human ecology courses
Friends of the Earth--conservation of the planet's ecology
San Francisco Planning and Conservation League--environmental legislation
"Cry California"--magazine on environment

These and many others at the county and local levels are interested in man's depletion of the environment. I wonder how many of these groups are involved in attacking the educational-science institutions for their "inquiry-collecting" habits? In my limited survey, all are concerned over man's technology and construction developments.

The popularity of marine science and marine field trips are ever increasing. Over 200 coastal high schools in the United States are reported to have specialized marine courses. Marine courses at the higher education level contribute significant numbers of students to the marine environment--in fact, it is a geometrical ratio--each graduate student who teaches in school systems adds percentages more to the masses of students flocking to the seashores. To illustrate the growth of marine educational facilities on the Pacific Coast: in 1958, there were 16 marine

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[33] Harold Gilliam, "Study of the Home", San Francisco Chronicle, This World, September 7, 1969, p. 27.

laboratories, and ten years later, 1968, the number had grown to 48.[34] Finally, no one is able to compile the numbers of elementary students participating in marine science units and eventually visiting the seashore; the projected numbers must be staggering!

In view of such pressure on the marine environment, this research study may be one of the most important documentations of the behavior of man in relationships to a specific environment. Perhaps such information may lead to the understanding of how man will react to other natural environments--desert, tropical, fresh water, etc. Lastly, the study may pave the way for conservation legislation to set aside many intertidal areas in California as "marine reserves"--environments where organisms are protected for future Californians to enjoy.

D. SPECIFIC RESEARCH GOALS

The research will cover the historical collecting of marine organisms on Duxbury Reef; the numbers of visitors and the areas from which they come; the numbers of organisms collected; the groups of people that collectors represent; and the correlation of the distribution of marine organisms to all reef visitors during the period of specific study. Against this collecting background, the study's major emphasis is to determine the effects of conservation education on the school population and general visitors to the reef. The pertinent hypothesis to this major emphasis is:

> The introduction of conservation education does enhance the ecology of a marine intertidal environment by changing the collecting behavior of the reef visitors; in turn, there will be a noticeable stability in the distribution of marine organisms.

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[34] David H. Montgomery, Directory of Marine Science Programs and Facilities on the Pacific Coast (San Luis Obispo, California: California State Polytechnic College, 1969)

CHAPTER II

SAMPLING METHODS AND PROCEDURES

A. PROBLEM AND HYPOTHESES

As previously stated on pages 9 and 10, marine animals on intertidal reefs close to urban areas are decreasing in numbers. In the meantime, general visitors and school populations are increasing their visits to these reefs. Man has been collecting marine life from these reefs for a number of years, and unless such collecting is curbed by conservation education, irreparable damage to the marine ecology will occur on these marine habitats.

Major Hypothesis

If the collecting of marine organisms by man from intertidal reefs in recent years constitutes the chief reason for the declining marine life populations, the introduction of conservation education at the site of such a reef will enhance the ecology of this marine intertidal environment by reducing the collecting done by reef visitors. As a result, there will be a noticeable stability in the distribution of marine organisms.

Supporting Hypotheses

1. A reef area frequently visited by general public and school groups will show a lower count of major marine organisms per square meter than a reef area which is rarely visited by man.
2. When conservation education in the form of signs and literature is introduced at the reef site, the amount, as well as the frequency,

of collecting will be reduced.

3. When conservation education is introduced to school visitors in the form of a classroom lecture at the reef, there will be a reduced amount of collecting by these students.

Specific Research Investigations

In order to determine if man is the major cause of the changes in marine populations, some of the major related questions need to be answered:

1. Has there been a change in the physical factors of salinity, oxygen, and temperature over the past years that might have contributed to the decrease in numbers of marine organisms? Does DDT have any effect?
2. What organisms and how many of these organisms have been collected from the reef by man in the past years?
3. Do the reef areas where people frequently visit illustrate lower counts in major marine organisms than areas less frequently visited? Does the present rate of collecting reduce the number of marine organisms on the reef?
4. Which of the two groups, school students or general public, is most numerous on the reef, and which collects the most organisms?
5. Of the three school groups which visit the reef-- elementary, secondary, and college, which one collects the most organisms?
6. If conservation education is introduced at the reef site, will the instruction affect the behavior of collectors?
7. If conservation education does reduce the amount of collecting, will there be a stability of population numbers in the distribution of marine organisms?

Undoubtedly, there are many other variables and questions pertaining to the problem. However, these are, in my opinion, the most important for this initial phase of research into the correlation of man's activities to the distribution of marine animals on a specified marine intertidal environment.

B. MARINE REEF LOCALITY

Duxbury Reef, one mile west of Bolinas, California, is located approximately twelve nautical miles or about twenty-five road miles northwest of San Francisco. The reef was named after the ship, Duxbury, which had crashed on these rocks on August 21, 1849. The reef, one of the largest exposed intertidal reefs in North America,[35] is composed of shale, called the Monterey formation, deposited during long periods of the Miocene Seas, some twenty-eight million years ago. The basement rock below this Monterey shale is granite diorite which is exposed at Point Reyes and at Tomales Point. In the late Pleistocene Epoch, during the past million-year interval, great block faulting took place along the whole California coast. It was probably during this time when the Monterey shale headland of Bolinas was uplifted from the seas to form a marine terrace. From this late Pleistocene Period down to present times, erosion by wind, rain, and ocean waves has cut the Bolinas Headland back, exposing much of the present Duxbury Reef and its vertical strata bedding planes[36] (see Appendix L, Figure 1).

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[35]Gordon Chan, The Conservation of Marine Animals on Duxbury Reef (College of Marin Press, Kentfield, California, 1968), p. 6

[36]Olaf P. Jenkins, ed., Geological Guidebook of the San Francisco Bay Counties, Division of Mines, Bulletin 154 (State of California, December, 1951), pp. 95-106.

The selection of Duxbury Reef as the test site for this research project is based on three important criteria:

1. The reef is close to urban populations and has a steady stream of general public and school visitors the year around.
2. The reef is large and consists of four well defined areas created by erosion. Each area has a different density of visitors. Only three areas, which I have designated as areas A, B, and C, will be included in this research. The fourth area has a sandflat surface which is not ecologically similar to the other three rocky areas. Area A, called Agate Beach, is closest to the parking lot and has more visitors than area B, the Agate Reef Annex, and area C, the major headland reef. Area C is patterned with large flood channels which make it difficult to visit as compared to areas A and B. Area C is also the least accessible to visitors. Thus, area C, with the same physical conditions as areas A and B and with a relatively larger and less collected population of marine animals, is designated as the control reef area in this research project. Figure 1 on page 20 is a sketch of the physical dimensions of the reef as measured in the summer of 1968 by my students and myself.[37]
3. The major access to the reef is a small trail down to Agate Beach, area A. Nearly all reef visitors park in the parking lot and go down the trail to the reef; few individuals try to climb down the steep, hazardous cliff to areas B or C. This funneling of visitors through one opening will enable the counting of marine animals collected from the reef and provide nearly total coverage of the visitors with conservation education materials.

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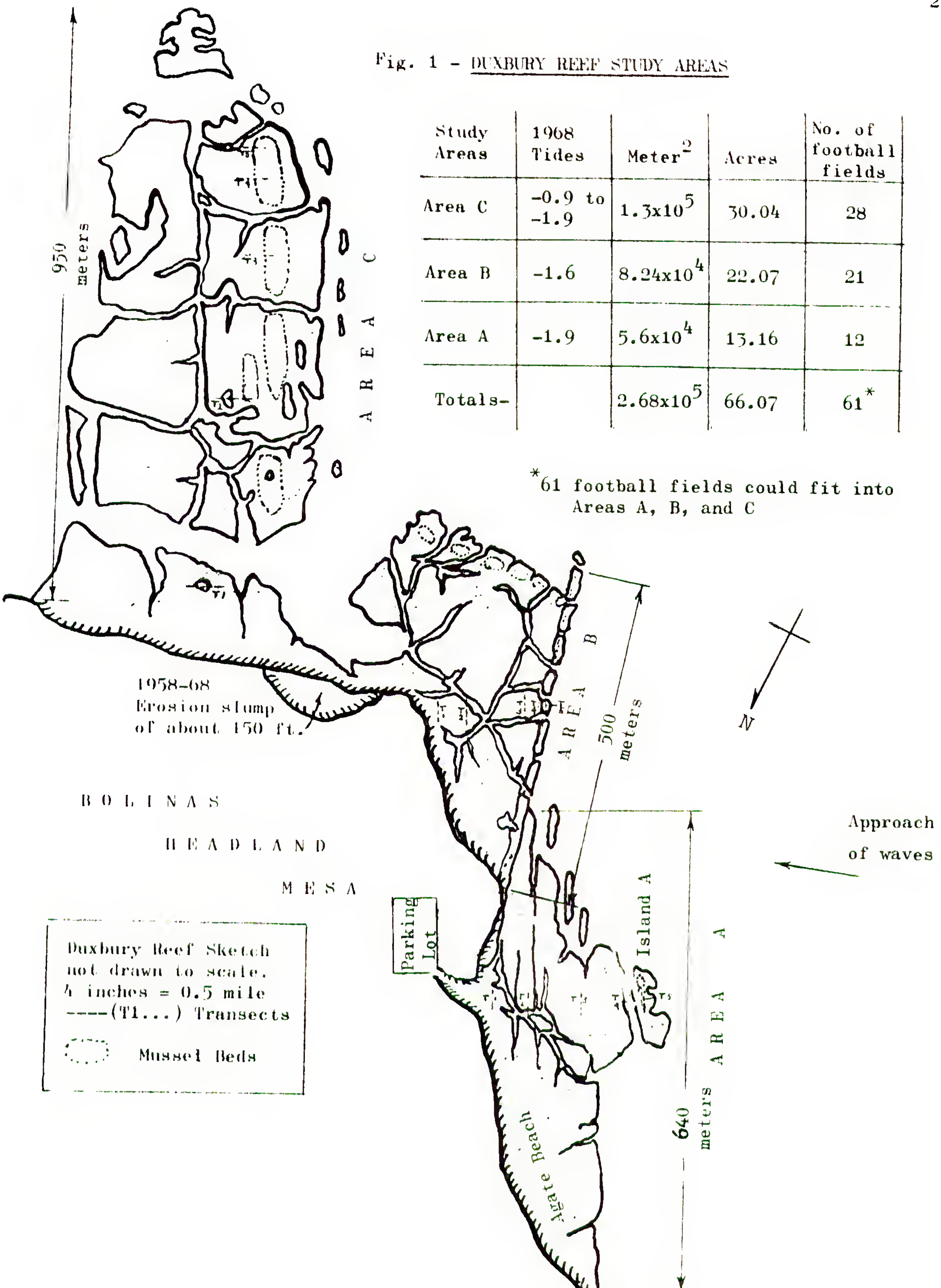
[37] Chan, pp. 3-9.

Fig. 1 - DUXBURY REEF STUDY AREAS

Study Areas	1968 Tides	$Meter^2$	Acres	No. of football fields
Area C	-0.9 to -1.9	$1.3x10^5$	30.04	28
Area B	-1.6	$8.24x10^4$	22.07	21
Area A	-1.9	$5.6x10^4$	13.16	12
Totals-		$2.68x10^5$	66.07	61*

*61 football fields could fit into Areas A, B, and C



C. SAMPLING AND RESEARCH PROCEDURES

1. Selection of the Research Time Period

The analysis of what people do on a marine intertidal reef is governed by a few basic considerations:

a. The tidal cycles that enable people to walk on to the reef

b. The favorable weather patterns

c. The availability of free time for the visiting public

According to the tide tables produced by the United States Coast and Geodetic Survey and reproduced by sport stores for the general public, the most favorable tides come in early summer, May through July. During this period of time, there are excellent minus low tides and they occur during ideal daylight morning hours. From August through March, the low tides are less favorable and they occur during evening or early morning hours. The weather conditions during these same winter months are also detrimental to comfortable visitations. In past years, I have noted that the greatest numbers of visitors to the reef begin with the Memorial Day weekend in May.

Therefore, the time period selected was from the Memorial Day weekend in May through the month of July and the first week of August. During this time the low tides and reef conditions are ideal and the early summer weeks seem to be the peak period when the public springs forth to the marine outdoors. Moreover, the early summer weeks cater to the many special marine biology classes taught in the elementary and secondary San Francisco Bay area summer schools.

2. Development of the Control and Treatment Sample Procedure

Two separate five-week time periods were set up for study:

the first for control sample, the second for treatment sample.

a. Control Sample

The time from May 30 through July 3, a period of five weeks, was designated as the control sample period, when there was no conservation education given and a record was kept of the activities of all visitors to the reef.

b. Treatment Sample

The time from July 4 through August 7, a period of five weeks, was designated as the treatment sample period, when conservation education was given to all visitors and a record was kept of the activities of all visitors to the reef.

c. Comparison of Control and Treatment Samples

From the observations of the two samples, the following data will be compared:

(1) The total number and average per day of visitors to the reef

(2) The home areas of the reef visitors

(3) Comparisons of school and general public visitors

(4) The specific activities of visitors to the reef

(a) fishermen

(b) rock clam fishermen

(c) collectors of living animals (number collected was counted)

(d) collectors of other reef materials (shells, rocks and agates, driftwood, glass, etc.)

(e) collectors of unknown items and/or quantity (These visitors were seen collecting from the reef, but the nature of the organisms collected could not be determined or the number collected could not be counted.)

(f) non-collectors

(5) The numbers of living marine animals collected in each area for each five-week time period

(6) The characteristics of school visitors-- elementary, secondary, college

(7) The proportion of school visitors who collect in each school group-- elementary, secondary, college

(8) Correlation of the number of animals collected to the number of visitors

(9) Determination of the effects of conservation education on visitor behavior and consequently, on the density of marine organisms.

During both sample periods, investigators (teachers and students) followed and carefully observed the reef visitors, counting all animals that were collected. Some estimations were necessary, especially when large numbers, bucketfuls, of snails were picked up. However, in my opinion, the data reflected about a 95% accuracy of numbers. Appendix H is the tally sheet used by the investigators.

3. Measurement or Count of the Density of Marine Animals during the Control and Treatment Sample Periods

To determine the effects of people pressure on the marine reef animals, base count transects were set up in each of the reef areas. The reef was transected every thirty meters, each transect being ten meters long. By random drawing of transect numbers, five transects were selected for each area A,B, and C, a total of fifteen. They were numbered from transect 1 (T-1) beginning at the beach trhough transect 5 (T-5) at the outer portion of each

reef area (Figure 1 on page 20). Sampling was taken along the ten-meter transect, at each meter:

Area A, 5 transects = total of 50 square meter sample counts
Area B, 5 transects = total of 50 square meter sample counts
Area C, 5 transects = total of 50 square meter sample counts

Each transect was marked by driving galvanized nails at each end of the transect line. When measurements were taken, a line was stretched between the transect nails and a square meter frame was used as a "flip-flop" perimeter for counting marine organisms along the ten-meter line. The square meter transect method was adopted from the research method taught by my ecology professor, Dr. Ralph Johnson of the University of the Pacific's Pacific Marine Station at Dillon Beach, California.[38] This transect procedure is used throughout the world and is especially detailed in methodology by the famed English marine biologist A. J. Southward.[39]

The number of square meter counts, 50 for each reef area, is deemed adequate for rocky marine intertidal shores by Southward,[40] although the more samples, the greater the validity of sampling. Due to the great undulation and unconformity of a rocky reef, no exact map of the transects is presented in this paper; however, the approximate locations can be seen in Figure 1 on page 20. Relocating the transects was accomplished by finding the nails. Future investigators may use thirty-meter interval measurements to locate the transect lines.

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[38] Ralph G. Johnson, W. R. Bryant, and Joel W. Hedgpeth, Ecological Survey of Tomales Bay, (Dillon Beach, California, Pacific Marine Station, No. 1, March, 1961), pp. 1-12.

[39] A. J. Southward, Life on the Sea-Shore, (Cambridge: Harvard University Press, 1965), pp. 121-139.

[40] Southward, p. 127.

The base counts were taken at the following times for all three areas A, B, and C:

Base Count 1, May 28-31, just before control sample period.
Base Count 2, July 1-4, end of control sample period, just before the treatment sample period.
Base Count 3, August 4-7, end of treatment sample period.

The objective of the base counts was to provide the following information:

a. The changes in density, if any, of marine animals between the three base counts (change between beginning and end of control sample of no conservation education; change between beginning and end of treatment sample of conservation education)

b. The comparison of base count means (averages per square meter) between areas A, B, and C, for each sample period.

c. Correlation of base count means to the amount of collecting activity of visitors in each sample period, control and treatment.

4. General Conservation Education of Reef Visitors

During the control period, the first five weeks, May 30-July 3, no conservation education was given to reef visitors. During the treatment period, the second five weeks, July 7-August 4, conservation education was given to all reef visitors. The major emphasis in the conservation education goal was to present the information in such a manner that it would elicit some measureable response from the visitors. Three methods of conservation education were employed:

a. A reef sign was posted at both ends of the parking lot, and in such a location that nearly all reef visitors would see the

signs. These signs were professionally constructed with blue lettered words carved on three-feet by four-feet redwood boards. The sign reads:

> "Please help preserve this area in its natural state. Observe and study the tide pool life but please let it remain for others to enjoy."

b. A handout of photos (Appendix L) was given to each reef visitor. Whereas the words on the sign reflected a positive tone, the handout accused man of being a predator.

c. A questionnaire on setting up a marine reserve was included with the handout, and return of the questionnaire by mail was optional. Summary of the responses is in Appendix K.

d. In addition, a response and behavior test was given only to school groups, not to general public. The next section explains the details of this test.

No attempt was made to disrupt the reef visitor while he was on the reef. Following the same procedure used for the control period, student and teacher project researchers observed and counted the organisms collected or disturbed in this treatment period. In general, organizations concerned with conservation education use signs and handouts. Occasionally, organized lectures are given to select groups. In this research, conservation education was given in all three forms of instruction to affect response and behavior from the reef visitors.

5. <u>Conservation Testing of School Groups during Treatment Period</u>

The major purpose of testing the school groups is to determine if the introduction of conservation education will change the behavior of school visitors on the reef (Appendix I).

a. Test Questions-- The test consisted of five questions relating to these various aspects of conservation behavior:

(1) Do not collect marine animals for home and school purposes.

(2) Return all marine animals to their exact environmental niches.

(3) If you turn over a rock for observation, return it to its original position.

(4) Do not tear up seaweed or rocky substrate to remove marine animals.

(5) Walk carefully on the reef, to disturb the least amount of marine life.

b. Steps of Testing-- Each visiting school class, before it went on the reef, was given a lecture by me or my assistant which contained questions regarding the forementioned five aspects of conservation behavior. The class was asked to respond to each question by a show of hands. The class was rated by percentage, up to 100% on each question for a 100% positive conservation response, making a perfect total score of 500%. After each question and response, the proper conservation behavior was explained to the class. The total score of responses is called the <u>pre-test score</u>, referring to the <u>pre-conservation education attitudes</u> of the class. The school group was then allowed to go on to the reef.

The behavior of the school group on the reef was then rated from 0% to 100% on each of the same five aspects of conservation behavior: 0% for no conservation behavior, 100% for perfect conservation behavior for entire class. This reef scoring of the group behavior is called the <u>post-test score</u>,

which indicated post-conservation education behavior.

c. An Example of the Sequence on One Question-- Before the class goes on to the reef, this class of sixth graders is questioned as to how many have picked up marine animals and transported them from their exact niche to someplace else (tidepool to tidepool). Since 60% raise their hands, a pre-test score of 40% is given, for 40% did not move animals from their exact niche. In the conservation instruction lecture, the class is told how each marine animal is suited to its particular niche and might die if transported to another area. As the class moves out over the reef, the students are observed as to how many do transport the animals from place to place. Since only 30% transported animals, a post-test score of 70% is given, for 70% of the class practised conservation behavior on this particular aspect, an improvement of 30%.

The objective of the test is to determine if there is a significant difference between the pre-test responses of students to conservation questions and the post-test behavior of these students on the reef after the conservation lecture. An analysis of the responses was made for each school group-- elementary, secondary and college. Such response-behavior testing is important for the survival of marine life on intertidal reefs, and perhaps the analogy of testing may be related to other natural environments visited by school groups.

6. Physical Measurements of Oxygen, Salinity, Temperature

The objective of determining oxygen, salinity, and temperature is to record any major variations from past records, as well as variations between the three reef areas, and to conclude if

these changes, if any, affected the density of marine organisms on the reef. The methods for calculating these three water quality factors were:

a. Dissolved oxygen-- analytical procedure was the Winkler Titration Method[41] for determining milliliters of dissolved oxygen per liter.

b. Salinity-- use of the Beckman Portable Salinometer, Model RS 5-3, calibrated on Copenhagen Standard Seawater by the University of California, Institute of Marine Resources Salinometer, Model 6220. Determination of salinity was in parts per thousand.

c. Temperature-- use of standard centigrade thermometer, measuring to the nearest tenth.

7. <u>Gathering Past Data on the Collecting of Marine Organisms on Duxbury Reef</u>

Various methods were used to gather information about past collecting practices on Duxbury Reef. Past data on collecting by general public is admittedly vague and difficult to obtain. However, data on collecting practices by school teachers and their students was easier to obtain and more accurate. The following methods were used for gathering data on collecting activities:

a. A questionnaire was sent to all elementary, secondary, and college teachers in Marin County, asking them about their collecting from 1961-1969 (Appendix C). Their replies represented a sample of the school populations who collected on Duxbury Reef.

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[41] M. M. Ellis, B. A. Westfall, and Marion D. Ellis, <u>Determination of Water Quality</u>, (Washington, D.C., U.S. Government Printing Office, Research Report No. 9, 1948) pp. 10-24.

b. A daily record covering five years was available concerning the teachers and students who were channeled through the Bolinas Marine Station to the reef.

c. A seventeen-day data sheet for 1968 was tabulated by a fellow teacher and his students on their observations of visitors on the reef.

d. Finally, I used data I had personally collected on field trips to Duxbury Reef over a period of ten years, 1960-1969.

The information gathered from past years is not as consist-and as accurate as the ten-week summer research project data. Since past data is somewhat incomplete, only the raw totals of the past years will be presented in this report.

8. <u>Statistical Procedures</u>

Appendix A presents the statistical terminology and formulas used in this research paper. The population numbers, particularly the confidence intervals for the population mean and the population proportion, were determined from the data obtained in the sample, using Z tables for samples greater than 30 and 5 tables for samples of 30 or less.

The 95% confidence interval is used consistently in this research to determine the interval within which we may expect to population mean or population proportion to be. If, on the basis of repeated sampling, 95% confidence intervals for the population mean, μ , are set up, then approximately 95% of these confidence intervals will actually contain the true mean, μ .

CHAPTER III

PRESENTATION OF DATA

NUMBERING OF CHARTS, GRAPHS, TABLES, PHOTOS

The numbering system of the many charts, graphs, tables, and photos is based on the category of data presented:

1.	Past Data pages 33-38	Use of regular system of numbering according to type: chart, graph, etc.- Table 1, Table 2, Graph 1, Graph 2.
2.	Control Sample Data and Treatment Sample Data pages 39-57	Use of numbering system disregarding type: chart, graph, etc.—with prefix letters C to represent Control and T to represent Treatment—Table C1, Table T1, Table C2, Table T2, Chart C3, Chart T3, Table C4, Table T4- in order to facilitate comparisons between control and treatment samples. Graph CT 14, page 57, combines the summaries of control and treatment.
3.	Base Count Data pages 58-60	Use of regular numbering system according to type: chart, graph, etc.—with the prefix letter B to represent Base Count—Table B1, Graph B1.
4.	Conservation Summary Data pages 61-66	Use of regular numbering system according to type: chart, graph, etc.—with the prefix letter S to represent Summary-Graph S1, Graph S2, Table S1.

In all cases, the number, i.e., Graph B2, and the page number will be used in the descriptive writings to pinpoint the exact reference. (If this research dissertation is presented in a published book form, all charts, graphs, tables, and photos will probably be labeled as figures- Fig. 1, Fig. 2, etc.—consecutively to conform to other scientific books.)

A. COMPARISONS OF PHYSICAL FACTORS OF SALINITY, OXYGEN, AND TEMPERATURE OF PAST YEARS TO THE 1969 RESEARCH DATA OF DUXBURY REEF

Table 2 below compares the available data of past years to the present 1969 research data on Duxbury Reef. Past data was available only from Fort Point, under the Golden Gate Bridge. The only other Duxbury Reef data was some sampling I performed in the summer of 1964.

TABLE 1 COMPARISONS OF AVAILABLE PHYSICAL MEASUREMENTS OF PAST YEARS TO THE PHYSICAL MEASUREMENTS OF THE 1969 RESEARCH PERIOD

Oxygen, dissolved, ml/liter	
July, 1923 = 5.34 ml/liter	average for three weeks of measurements at Fort Point[42]
1969 = 2.6 ml/liter	average for 1969 research period at Duxbury Reef
Salinity, o/oo	
1922-1954 = 28.2 to 31.0 o/oo	Salinity (titration) range at Fort Point[43]
1922-1954 = 30.8 o/oo	average for the July months of these years
1964 = 32.2 o/oo	average salinity (titration) for June and July on Duxbury Reef
1969 = 33.6 o/oo	average salinity (salinometer) for research period on Duxbury Reef
Temperature, C^{o}	
July, 1923 = 14.2 C^{o}	average for three weeks of measurements at Fort Point[44]
1964 = 13.7 C^{o}	average for June and July on Duxbury Reef
1969 = 12.3 C^{o}	average for research period on Duxbury Reef

[42] R. C. Miller, W. D. Ramage, and E. L. Lazier, "A Study of Physical and Chemical Conditions in San Francisco Bay, Especially in Relation to the Tides", Zoology (Berkeley: University of California Press, 1928) pp. 201-267.

[43] U.S. Coast Geodetic Survey, Surface Water Temperatures and Salinity, Pacific Coast, Washington, D.C., Supt. of Documents, Publications 31-3, 1962.

[44] Miller, pp. 201-267.

TABLE 2 MEANS AND INTERVALS OF PHYSICAL FACTORS, 1969

AREA	CONDUCTIVITY Lo Hi	n	$\overline{X}$	TEMPERATURE °C Lo Hi	n	$\overline{X}$	SALINITY o/oo Lo Hi	n	$\overline{X}$	OXYGEN ml/liter Lo Hi	n	$\overline{X}$
A	38.1 40.6	4	39.5	11.45 13.4	4	12.5	31.6 34.8	4	33.7	2.21 2.61	3	2.39
B	37.8 40.2	4	39.4	11.5 13.4	4	12.4	31.5 34.8	4	33.5	2.33 2.99	3	2.68
C	38.9 39.4	4	39.1	10.76 13.1	4	11.9	31.9 34.7	4	33.7	2.48 2.91	3	2.74
ALL AREAS:			39.3			12.3			33.6			2.60
				95% CONFIDENCE INTERVALS for population mean (μ)								
A	$37.8 \leq \mu_A \leq 41.2$			$11.2 \leq \mu_A \leq 13.8$			$31.3 \leq \mu_A \leq 36.1$			$1.91 \leq \mu_A \leq 2.87$		
B	$37.7 \leq \mu_B \leq 41.1$			$11.0 \leq \mu_B \leq 13.8$			$31.2 \leq \mu_B \leq 35.8$			$1.86 \leq \mu_B \leq 3.50$		
C	$38.7 \leq \mu_C \leq 39.5$			$10.2 \leq \mu_C \leq 13.6$			$31.6 \leq \mu_C \leq 35.8$			$2.18 \leq \mu_C \leq 3.30$		

Table 2 above gives the major physical measurements of each area of Duxbury Reef as:

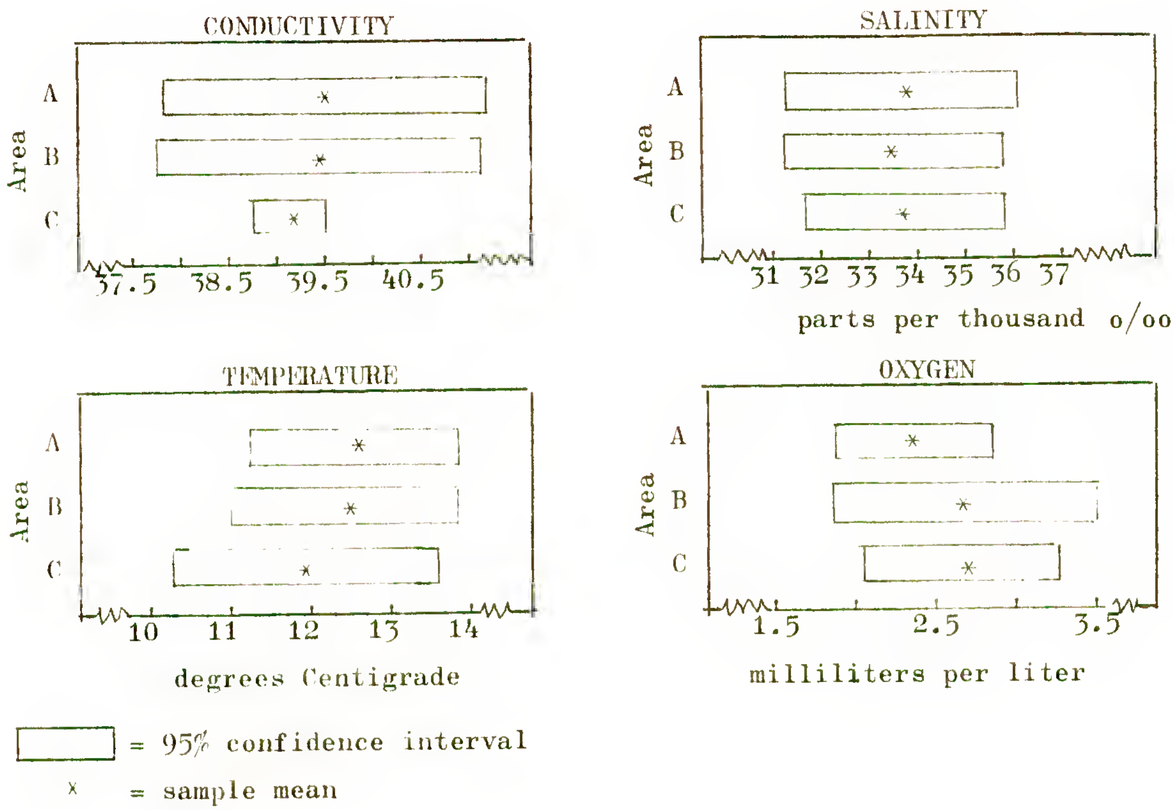
Temperature in degrees centigrade (°C)
Salinity in parts per thousand (o/oo)
Oxygen in milliliters per liter (ml/liter)

Conductivity data is given as information to support the role that salinity is a function of electrical conductivity and temperature as measured by the RS5-3 salinometer.

The number (n) of individual readings and measurements taken is given for each area; Appendix B provides additional data for each sample.

The 95% confidence intervals are also listed for each area's physical measurements.

GRAPH 1 MEANS AND INTERVAL RANGES OF THE PHYSICAL FACTORS, 1969



In graph 1 above, the major measurements of salinity, temperature, and dissolved oxygen for each area of Duxbury Reef is illustrated by its mean (x). The line bar, , provides the 95% confidence interval estimates of the population mean for each physical factor in each area. For example (Appendix A), the 95% confidence interval simply states that in repeated random sampling of data, the population mean would occur within the 95% confidence interval ranges of 95% of the samples taken.

B. MARINE ANIMALS COLLECTED IN PAST YEARS, 1961-1969

The raw data of the following pages, 36-38, was compiled from three sources: (1) a questionnaire survey of Marin County teachers conducted by G. Chan for the years, 1961-1969, (2) a seventeen-day survey in 1968 by a San Rafael High School teacher, Mr. Larry Lack, (3) the log book data of reef visitors who passed through the Bolinas Marine Station.

The dates of the above data were checked and compared to avoid duplication of data in the totals used for preparing the following:

1. Graph 2a Total Number of School Visitors for Days Observed and Graph 2b Average Number of School Visitors per Day, page 36

2. Table 3 Living Marine Animals Collected by School Visitors, page 37

   This table lists the total number collected by species for each year. It also shows the total number of animals collected each year and the number of observed school collectors each year. The 1969 data included the observed days from January through the research control period to July 3rd inclusive. These observed days represented days in which visitors were not influenced by any method of conservation education at the reef.

3. Graph 3 Comparison of Average Number (of marine animals) Collected, page 37

4. Graphs 4a and 4b The Collecting Preference by School Groups, page 38

   These graphs illustrate the total number of marine animals by species collected by school groups:

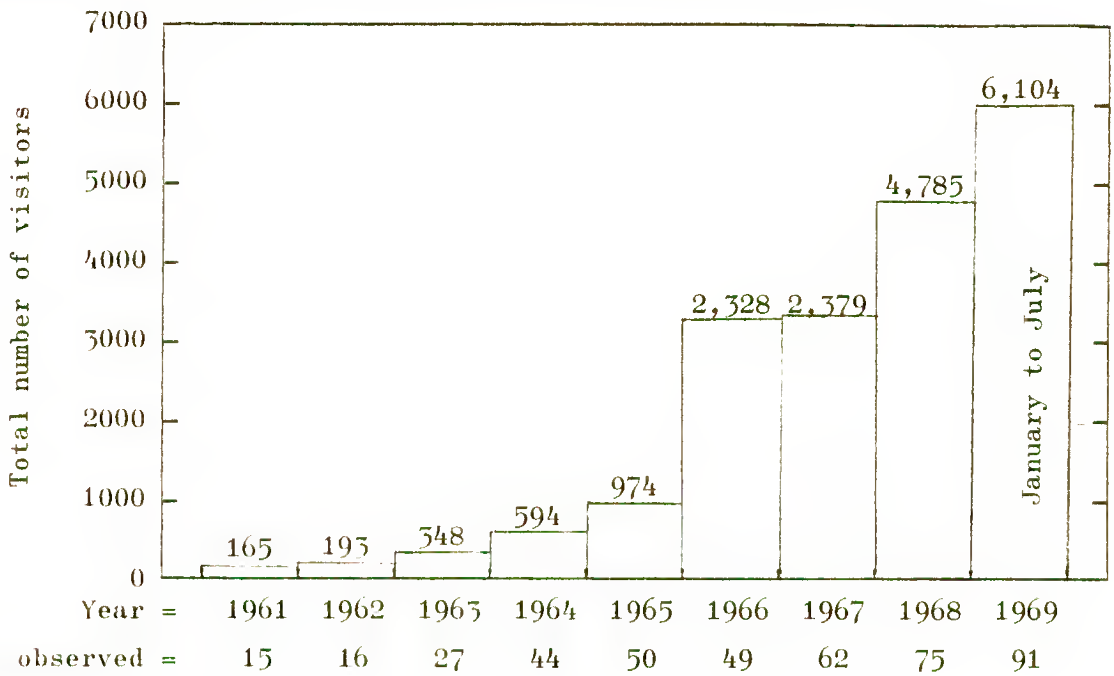
   a. The total number of marine animals by species collected by elementary school visitors

   b. The total number of marine animals by species collected by secondary and college visitors

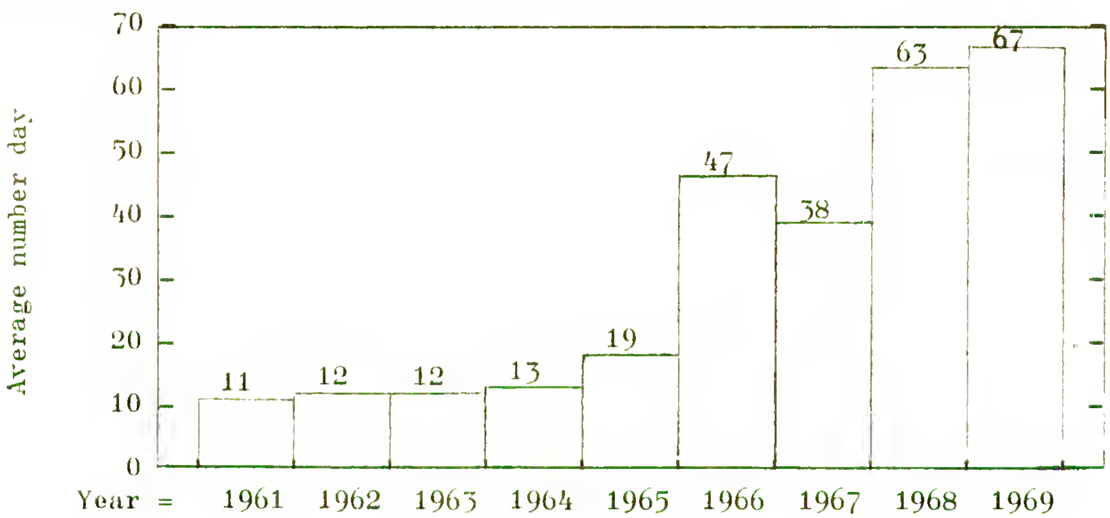
GRAPH 2 NUMBER OF DUXBURY REEF SCHOOL VISITORS

1961-1969

a. Total Number of School Visitors for Days Observed, 1961-1969*



b. Average Number of School Visitors per Day, 1961-1969



* Data taken from summaries provided by:

G. Chan, Inventory Study of Teachers, 1961-1969
San Rafael High School 17-day survey, 1968
Bolinas Marine Station Visitor Summary, 1965-69

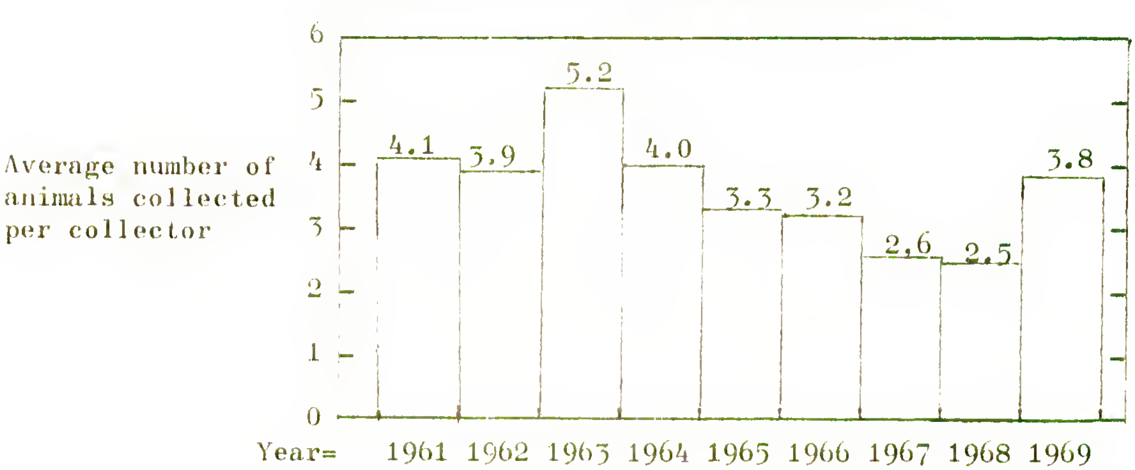
TABLE 3 LIVING MARINE ANIMALS COLLECTED BY SCHOOL VISITORS, 1961-1969

Animals are listed according to highest total collected.

	YEAR									
	1961	1962	1963	1964	1965	1966	1967	1968	1969*	Total
Tegula funebralis	42	42	97	163	253	103	135	114	1055	2,004
Various Crustacea	98	100	145	177	134	110	114	333	419	1,630
Mytilus californianus	72	60	126	171	168	156	138	158	127	1,176
Acmaea spp.	71	167	86	109	140	75	68	98	109	923
Mopalia mucosa	79	43	56	114	109	80	75	96	132	784
Pisaster spp.	80	50	63	190	169	54	53	60	55	774
Strongylocentrotus purpuratus	59	54	90	85	138	80	65	85	29	685
Anthopleura xanthogrammica	21	22	90	54	65	30	24	29	17	352
Fish - sculpins	22	32	30	37	29	32	25	36	37	280
Platyodon cancellatus	13	10	21	41	21	11	14	14	45	190
Various Nudibranchs	-	-	-	-	-	-	-	-	55	55
Other animals	-	-	-	-	-	-	-	-	32	32
Total Collected/year	557	580	804	1141	1226	731	711	1023	2112	8,885 animals
Number of observed school collectors	135	147	156	285	377	232	275	402	556	2,565 collectors
Avg. no. of animals collected/collector	4.1	3.9	5.2	4.0	3.3	3.2	2.6	2.5	3.8	

* January through July 3, 1969

GRAPH 3 COMPARISON OF AVERAGE NUMBER COLLECTED



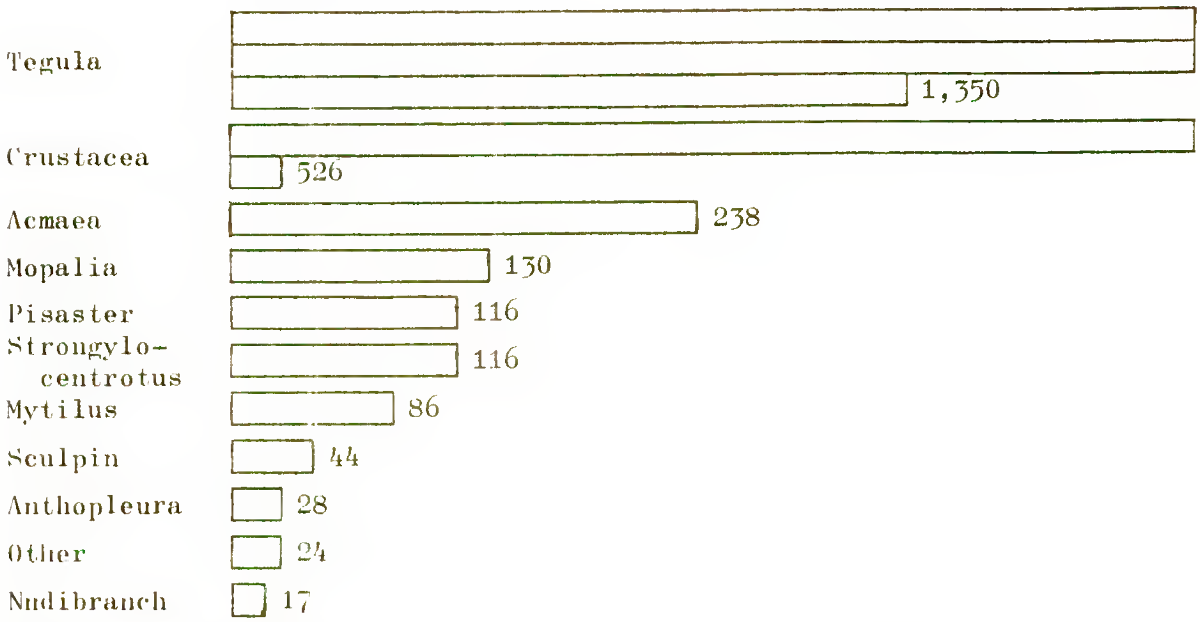
GRAPH 4 COLLECTING PREFERENCE BY SCHOOL GROUPS

Elementary vs. Secondary and College

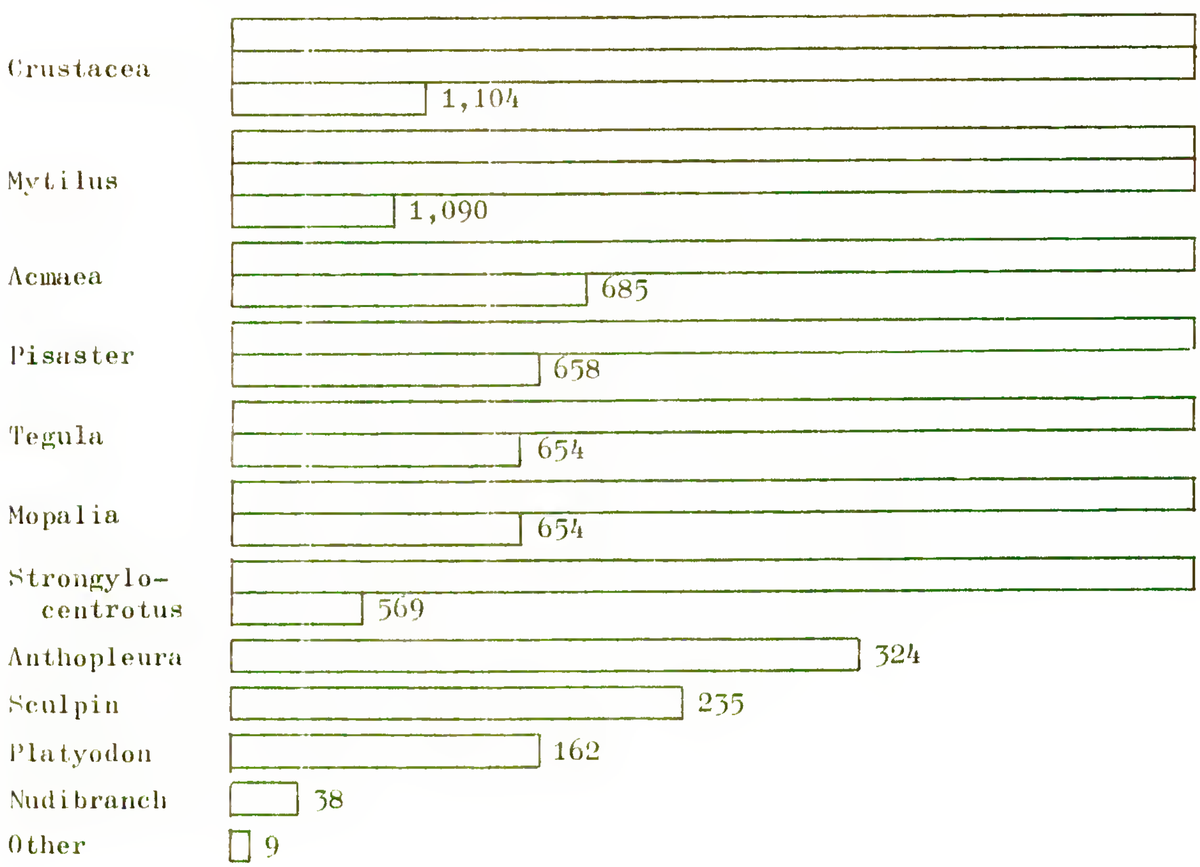
(1961 – 1969)

Scale: 1 inch= 100 animals

a.
Collecting by Elementary school visitors (2,703 animals; 1,156 collectors)



b.
Collecting by Secondary and College school visitors (6,182 animals; 1,409 collectors)



C. COMPARISON OF CONTROL SAMPLE DATA (first five weeks) TO TREATMENT SAMPLE DATA (second five weeks)

The following list describes the data, pages 44-57, of the control sample (C) and the treatment sample (T), placed side by side for comparison. The tables, graphs, and charts are regarded as equal units and number 1 through 13, regardless of type of presentation. For example, the only graph in this comparison data for the two samples, is numbered C7 and T7, because that is the place this graph occupies in the order of data presentation in this section. This method was chosen because there is corresponding data for each of the samples and keeping the numbers uniform for both samples facilitates references to this data in interpretation and analysis.

1. Tables C1 and T1 Reef Visitors, Tide Tables, page 44
   a. Daylight low tides for each day
   b. Times the low tides occur during daylight hours
   c. Total number of all visitors each day
   d. Total number of school visitors each day
   e. Total number of general visitors each day, or visitors other than school visitors
2. Tables C2 and T2 Home Areas of Reef Visitors, page 45
   a. Numbers of all visitors and their general home areas
   b. Numbers of school visitors and their general home areas
   c. Numbers of general visitors and their general home areas
   d. A breakdown of the general home areas into specific towns of California, and states for visitors from outside California
3. Charts C3 and T3 Home Areas of Reef Visitors, page 46

   The numbers of school and general visitors to the whole reef are compared according to the general home areas of the visitors.

4. Tables C4 and T4 Reef Visitors - Summary, page 47

   a. Comparison of number of visitors, school and general, to the home areas of Marin or non-Marin

   b. Comparison of the average number of visitors per day, school and general, to the home areas of Marin or non-Marin

   c. Comparison of the percentage of visitors, school and general, to the home areas of Marin or non-Marin

   d. Pie diagram illustrating the percentage of school visitors to general visitors, and their home areas, Marin or non-Marin

5. Tables C5 and T5 Reef Areas (A,B,C) Visited, page 48

   Comparison of the numbers of reef visitors to the specific areas of Duxbury Reef, A,B, and C, school and general visitors in each reef area and the home areas of these visitors.

   Charts C5 and T5 Percentage of Visitors for Each Reef Area, page 48

   Illustrates and compares the percentages of total reef visitors who visit areas A, B, or C only or more than one area. The percentages of total reef visitors who come from Marin or non-Marin are shown for each reef area.

6. Tables C6 and T6 Reef Areas Visited --Continued, page 49

   Total numbers of school and general visitors to each Duxbury Reef area visited, according to Marin or non-Marin residency. A Venn diagram clearly shows the total numbers of visitors who visit each area and who visit more than one area.

   Charts C6 and T6 Comparison of School and General Visitors in Each Area, page 49

   An illustration of the total numbers of visitors to each area of Duxbury Reef, and comparison of those who visit only one area and those who visit two or three areas.

7. <u>Tables C7 and T7 Activity on the Reef, page 50</u>

Individuals on the reef are classified as:

Fishermen

Collectors of Rock clams

Living animals

Other (collectors of algae, shells, rocks, driftwood, glass, etc.)

Unknown (quantity or type of collecting data not availalbe)

Non-collectors

Total visitors, school and general, place of residence, and percentages for each category are also provided.

<u>Graphs C7 and T7 Comparison of Activity, by Percentage, page 50</u>

Midpoint percentage comparisons of the activities of Fishermen, Collectors, and Non-collectors, along with the place of residence, Marin or non-Marin.

8. <u>Tables C8 and T8 Activity on Each Reef Area, page 51</u>

Tables compare numbers and percentages of school visitor activity to general visitor activity on each reef area, with totals for all visitor activity on each area.

<u>Charts C8 and T8 Comparison of School and General Activity in Each Area, page 51</u>

Total numbers for activities of reef visitors are displayed for each reef area.

9. <u>Tables C9 and T9 Number of Living Marine Animals Collected, page 52</u>

The totals of the most collected marine species are compared by:

a. The areas where the species are collected

b. The numbers collected by school and general visitors, each

according to the home residence of the visitors

10. <u>Charts C10 and T10 Number of Living Marine Animals Collected in Areas A, B, and C, page 53</u>

The charts illustrate the number of each species collected by school visitors compared to general visitors, for each reef area.

11. <u>Tables C11 and T11 Observed Collectors of Living Marine Animals, page 54</u>

Selected species of marine animals, <u>Tegula funebralis</u> and <u>Platyo-odon cancellatus</u> (when collected at a minimum of 50 per collector), are compared to the other remaining species shown on Tables C9 and T9, as regards school collectors vs. general collectors, each according to home residence. The tables show:

a. Total numbers of collectors

b. Number of animals collected

c. Average number of animals collected per collector

d. Percentage of total collectors who are school collectors and general collectors, according to home area, Marin or non-Marin

e. Percentage of total animals collected by school or general visitors

12. <u>Tables C12 and T12 School Visitors, page 55</u>

A comparison of elementary, secondary and college visitors to the reef and record of the following:

a. Which area they visit

b. Number of collectors

c. Number of those who collect living marine animals, other, unknown, and those who do not collect anything

d. Total numbers of observed animals collected in each area A, B, and C.

13. Charts C13 and T13 - School Visitors, page 56

Elementary, secondary and college visitors are compared as to:

a. Number of visitors in each group

b. Activity on the reef- collector or non-collector

c. Number observed collecting living marine animals, according to the reef area

14. Graph CT14 Summary Comparisons of Number of Living Marine Animals Collected by Control and Treatment Sample Visitors, page 57

Summary illustrating the marine animals collected, by species, comparing control visitors vs. treatment visitors.

Table CT14 Summary Comparison of Control Sample and Treatment Sample, page 57

Table compares:

a. Number of reef visitors

b. Number of collectors

c. Living marine animals collected by number of collectors

d. Average number of living marine animals collected per collector

TABLE C1

REEF VISITORS

Control Sample
Weeks I – V
May 30 – July 3

Tide Tables

	Fri	Sat	Sun	Mon	Tue	Wed	Thu		
TIDES									
I	-1.4	-1.8	-2.0	-2.0	-1.8	-1.4	-0.9	(May 30 – June 5)	
II	-0.3	0.3	1.0	1.6	2.2	-0.3	-0.7	(June 6 – 12)	
III	-0.4	-0.9	-0.9	-0.8	-0.7	-0.6	-0.3	(June 13 – 19)	
IV	0.0	0.4	0.8	1.3	1.8	2.3	2.7	(June 20 – 26)	
V	-1.1	-1.6	-1.9	-2.0	-1.9	-1.6	-1.1	(June 27 – July 3)	
TIMES	(P.M. times are underlined)								
I	5:30	6:12	7:06	7:54	8:48	9:42	10:15		
II	11:15	12:18	1:18	2:00	2:48	4:24	5:06		
III	5:45	6:24	7:00	7:36	8:12	8:48	9:24		
IV	10:00	10:30	11:18	12:06	12:54	1:42	2:36		
V	4:24	5:18	6:06	6:54	7:42	8:30	9:12		
TOTAL VISITORS									
I	113	184	94	25	200	283	125	=	1,024
II	168	86	53	70	17	8	7	=	409
III*	7	41	24	9	14	12	67	=	174
IV	19	78	113	18	10	23	14	=	275
V	2	57	36	73	232	85	171	=	656
								Total =	2,538 (100%)
(Area D: 257 visitors for Weeks I–V)								sample mean =	72 visitors/day
School Visitors									
I	12	25	–	–	188	274	121	=	620
II	161	40	–	63	–	–	–	=	264
III*	–	–	8	9	–	–	–	=	17
IV	–	–	–	–	–	–	–	=	0
V	–	–	–	53	214	66	144	=	479
								Total =	1,380 (54.4%)
(Area D: no school visitors)								average of	39/day
General Visitors									
I	101	159	94	25	12	9	4	=	404
II	7	46	53	7	17	8	7	=	145
III*	7	41	16	0	14	12	67	=	157
IV	19	78	113	18	10	23	14	=	275
V	2	57	36	18	18	19	27	=	177
								Total =	1,158 (45.6%)
(Area D: 257 visitors for Weeks I–V)								average of	33/day

* beginning of summer vacation (Friday, June 13,–last day of spring semester)

Note: Area D information is NOT included in statistics and data analysis

TABLE T1

REEF VISITORS

Treatment Sample
Weeks VI – X
July 4 – August 7

Tide Tables

	Fri	Sat	Sun	Mon	Tue	Wed	Thu		
TIDES									
VI	-0.4	0.4	1.2	1.9	2.5	2.9	3.2	(July 4 – 10)	
VII	-0.5	-0.7	-0.8	-0.8	-0.7	-0.6	-0.4	(July 11 – 17)	
VIII	-0.1	0.4	0.9	1.5	2.1	2.6	3.0	(July 18 – 24)	
IX	3.2	-1.1	-1.5	-1.7	-1.7	-1.4	-0.9	(July 25 – 31)	
X	-0.2	0.5	1.3	2.0	2.7	3.1	3.3	(August 1 – 7)	
TIMES	(P.M. times are underlined)								
VI	10:00	10:48	11:30	12:24	1:12	2:06	3:00		
VII	4:48	5:30	6:06	6:42	7:12	7:42	8:12		
VIII	8:42	9:12	9:48	10:24	11:06	12:01	1:06		
IX	2:18	4:12	5:00	5:48	6:36	7:18	8:00		
X	8:42	9:18	10:00	10:42	11:30	12:30	1:42		
TOTAL VISITORS									
VI	92	68	29	15	8	18	14	=	244
VII	9	10	9	20	225	106	286	=	665
VIII	220	39	38	17	12	11	33	=	370
IX	10	13	5	58	129	57	36	=	308
X	14	10	42	9	20	40	18	=	153
								Total =	1,740 (100%)
								sample mean =	49 visitors/day
School Visitors									
VI	–	–	–	–	–	–	–	=	0
VII	–	–	1	10	209	62	239	=	521
VIII	190	–	–	–	–	–	21	=	211
IX	–	–	–	53	107	34	16	=	210
X	3	–	–	4	10	–	–	=	17
								Total =	959 (55.1%)
								average of	27 day
General Visitors									
VI	92	68	29	15	8	18	14	=	244
VII	9	10	8	10	16	44	47	=	144
VIII	30	39	38	17	12	11	12	=	159
IX	10	13	5	5	22	23	20	=	98
X	11	10	42	5	10	40	18	=	136
								Total =	781 (44.9%)
								average of	22 day

Note: No area D counts were taken because conservation signs were not used in this area.

TABLE C2 — HOME AREAS of REEF VISITORS — Control Sample, Weeks I – V, May 30 – July 3

Home areas:	Marin County	Bay Area	North Cal	East Cal	South Cal	Out of Cal	Un-known	Total	
ALL VISITORS									
I	457	202	45	33	11	–	276 =	1,024	(May 30 – June 5)
II	227	149	6	–	–	2	25 =	409	(June 6 – 12)
III*	113	38	–	19	2	2	– =	174	(June 13 – 19)
IV	127	78	2	9	11	2	46 =	275	(June 20 – 26)
V	426	135	–	10	78	7	– =	656	(June 27 – July 3)
	1,350	602	53	71	102	13	347	2,538	
(Area D = 257 visitors ?- home area unknown)									
	53.2%	25.7%	2.1%	2.8%	4.0%	0.5%	13.7%=	100%	
School Visitors									
I	401	167	40	12	–	–	– =	620	
II	158	106	–	–	–	–	– =	264	
III*	9	8	–	–	–	–	– =	17	
IV	–	–	–	–	–	–	– =	0	
V	307	97	–	–	75	–	– =	479	
	875	378	40	12	75	–	–	1,380	
(Area D = no school visitors)									
	63.4%	27.4%	2.9%	0.9%	5.4%	–	– =	100%	
General Visitors									
I	56	35	5	21	11	–	276 =	404	
II	69	43	6	–	–	2	25 =	145	
III*	104	30	–	19	2	2	– =	157	
IV	127	78	2	9	11	2	46 =	275	
V	119	38	–	10	3	7	– =	177	
	475	224	13	59	27	13	347	1,158	
(Area D = 257 general visitors from ? home area)									
	41.0%	19.4%	1.1%	5.1%	2.3%	1.1%	30.0%=	100%	

* beginning of summer vacation

Marin= Bolinas, Stinson Beach, Woodacre, Fairfax, San Anselmo, Larkspur, San Rafael, Corte Madera, Tiburon, Mill Valley, Susalito, Novato, Pt. Reyes

Bay Area= Richmond, Berkeley, Oakland, Alameda, El Cerrito, Castro Valley, Concord, Hayward, San Leandro, Orinda, Pinole, Martinez, San Francisco

North of Marin= Petaluma, Willits, Redding

East of Bay Area= Sacramento, Woodland, Lodi, Dixon, Davis, Auburn, Placerville, Stockton

South of Bay Area= Los Altos, Palo Alto, San Jose, Millbrae, Santa Cruz, Los Angeles

Outside California= Wisconsin, Wyoming, Oregon, Florida

TABLE T2 — HOME AREAS of REEF VISITORS — Treatment Sample, Weeks I – V, July 4 – August 7

Home areas:	Marin County	Bay Area	North Cal	East Cal	South Cal	Out of Bay A.	Out of Cal	Total	
ALL VISITORS									
VI	110	81	6	24	7	12	4 =	244	(July 4 – 10)
VII	573	33	42	8	–	–	9 =	665	(July 11 – 17)
VIII	326	31	–	4	4	–	5 =	370	(July 18 – 24)
IX	294	14	–	–	–	–	– =	308	(July 25 – 31)
X	101	29	–	5	14	–	4 =	153	(August 1 – 7)
	1,404	188	48	41	25	12	22	1,740	
	80.7%	10.8%	2.8%	2.3%	1.4%	0.7%	1.3%=	100%	
School Visitors									
VI	–	–	–	–	–	–	– =	0	
VII	459	22	40	–	–	–	– =	521	
VIII	211	–	–	–	–	–	– =	211	
IX	196	14	–	–	–	–	– =	210	
X	14	–	–	3	–	–	– =	17	
	880	36	40	3	–	–	–	959	
	91.8%	3.7%	4.2%	0.3%	–	–	– =	100%	
General Visitors									
VI	110	81	6	24	7	12	4 =	244	
VII	114	11	2	8	–	–	9 =	144	
VIII	115	31	–	4	4	–	5 =	159	
IX	98	–	–	–	–	–	– =	98	
X	87	29	–	2	14	–	4 =	136	
	524	152	8	38	25	12	22	781	
	67.1%	19.5%	1.0%	4.9%	3.2%	1.5%	2.8%=	100%	

Marin= Bolinas, Stinson Beach, San Geronimo, San Anselmo, Ross. San Rafael, Sausalito, Mill Valley, Novato. Tiburon, etc.

Bay Area= Richmond, Berkeley. Oakland. Orinda. Vallejo. Hayward, San Francisco, El Cerrito, Concord. Walnut Creek. Benicia

North of Marin= Willits. Santa Rosa. Petaluma. Sonoma

East of Bay Area= Davis. Livermore, Woodland. Sacramento. Pittsburg. Folsom, Fairfield

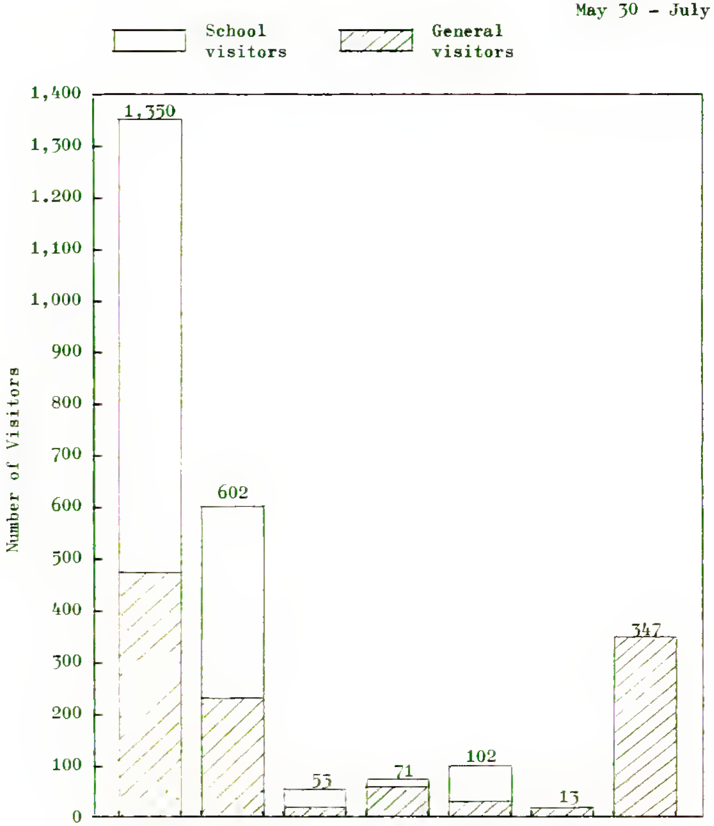
South of Bay Area= Redwood City. San Jose. Monterey. Norwalk. Union City

Outside of Cal: Colorado, Idaho. Ohio. Michigan. Wisconsin. Australia

CHART C3

HOME AREAS of REEF VISITORS

Control Sample
Weeks I – V
May 30 – July 3

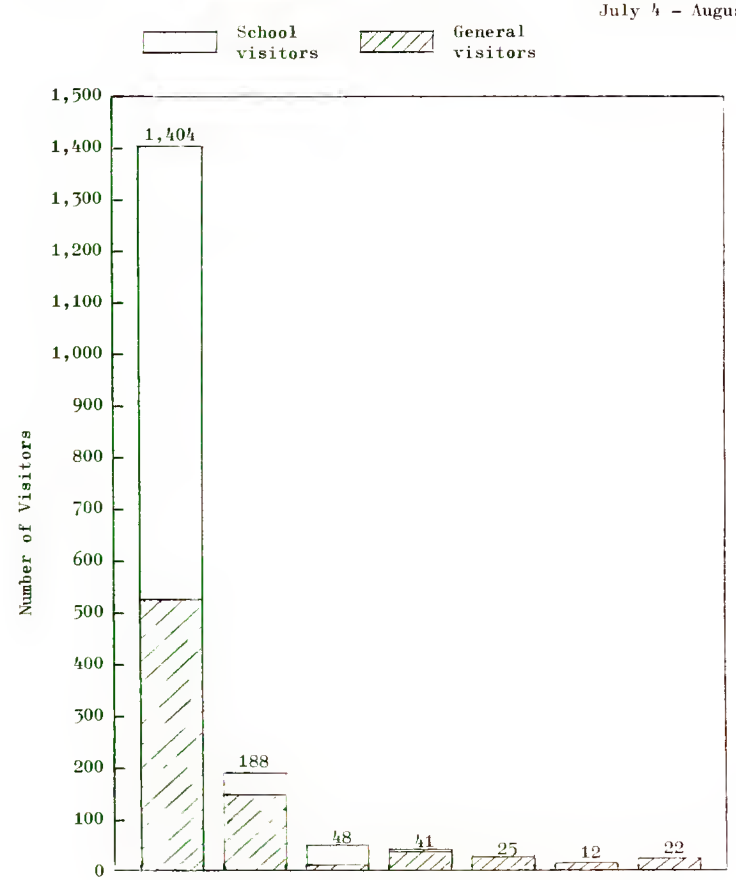


	Marin County	Bay Area	North Cal	East Cal	South Cal	Non-Cal	Unknown
School –	64.8	62.8	75.5	16.9	73.5	–	–
General –	35.2	37.2	24.5	83.1	26.5	100.0	100.0
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

CHART T3

HOME AREAS of REEF VISITORS

Treatment Sample
Weeks VI – X
July 4 – August 7



	Marin County	Bay Area	North Cal	East Cal	South Cal	Non-Bay Area	Non-Cal
School –	62.7	19.1	83.3	7.3	–	–	–
General –	37.3	80.9	16.7	92.7	100.0	100.0	100.0
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE C4

REEF VISITORS SUMMARY

Control Sample
Weeks I – V
May 30 – July 3

NUMBER of VISITORS

	School	General	
Marin	875	475	1350
N-Mar	505	336	841
Unknown	–	347	347
	1380	1158	2538 total visitors

AVG. NUMBER VISITORS/DAY

	School	General	
Marin	25	13	38
N-Mar	14	10	24
Unknown	–	10	10
	39	33	72 visitors/day

PERCENTAGE of VISITORS

	School	General	
Marin	34.5	18.7	53.2
N-Mar	19.9	13.2	33.1
Unknown	–	13.7	13.7
	54.4	45.6	100.0%

KEY for the percentage figure below:

Marin County visitors

Non-Marin Co. visitors

? ? Home area unknown

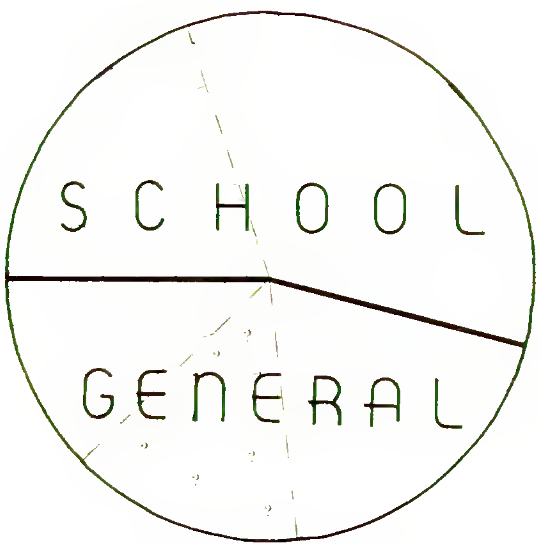


TABLE T4

REEF VISITORS SUMMARY

Treatment Sample
Weeks VI – X
July 4 – August 7

NUMBER of VISITORS

	School	General	
Marin	880	524	1404
N-Mar	79	257	336
	959	781	1740 total visitors

AVG. NUMBER VISITORS/DAY

	School	General	
Marin	25	15	40
N-Mar	2	7	9
	27	22	49 visitors/day

PERCENTAGE of VISITORS

	School	General	
Marin	50.6	30.1	80.7
N-Mar	4.5	14.8	19.3
	55.1	44.9	100.0%

KEY for the percentage figure below:

Marin County visitors

Non-Marin Co. visitors

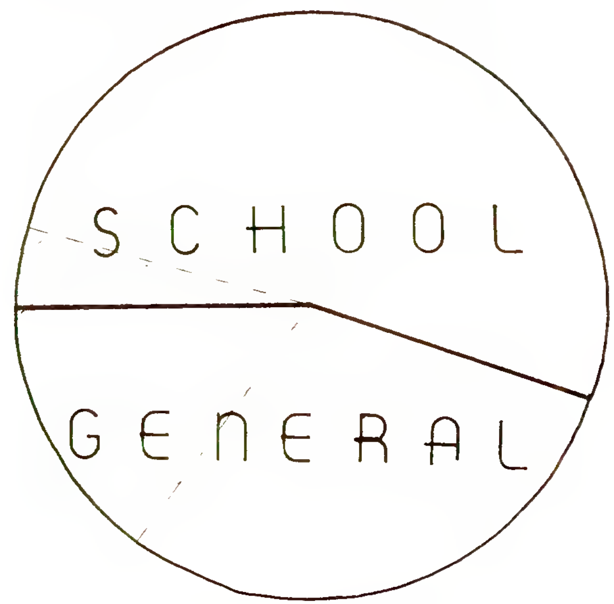


TABLE C5 **REEF AREAS VISITED**

Control Sample
Weeks I - V
May 30 - July 5

Number of Persons on Each Reef Area

	SCHOOL		GENERAL				
	Marin	Non-M	Marin	Non-M	Unknown		
Area A	827	497	336	256	263	2179	
Area B	184	166	160	74	54	638	
Area C	64	8	35	6	30	143	
(Area D)					(257)	(257)	memo only
	1075	671	531	336	347	2960	total count for A,B,C
	-875	-505	-475	-336	-347	-2538	total visitors
	200	166	56	-0-	-0-	422	extra count due to persons visiting more than one area. See Figure on next page.

CHART C5

school visitors

general visitors

PERCENTAGE OF VISITORS FOR EACH REEF AREA

M Marin County

N-M Non-Marin County

? Unknown home area

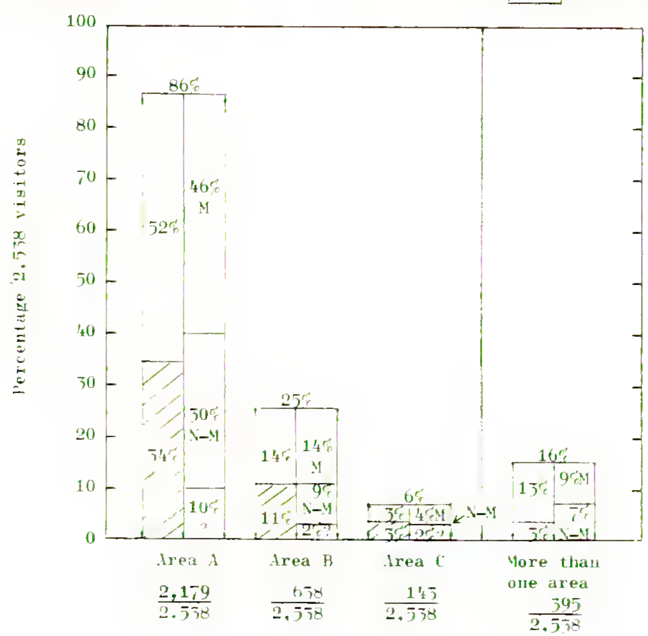


TABLE T5 **REEF AREAS VISITED**

Treatment Sample
Weeks VI - X
July 4 - August 7

Number of Persons on Each Reef Area

	SCHOOL		GENERAL			
	Marin	Non-M	Marin	Non-M		
Area A	833	76	428	222	1559	
Area B	325	43	100	59	527	
Area C	77	-	47	2	126	
	1235	119	575	283	2212	total count for A,B,C
	-880	-79	-524	-257	-1740	total visitors
	355	40	51	26	472	extra count due to persons visiting more than one area. See Figure on next page.

CHART T5

school visitors

general visitors

PERCENTAGE OF VISITORS FOR EACH REEF AREA

M Marin County

N-M Non-Marin County

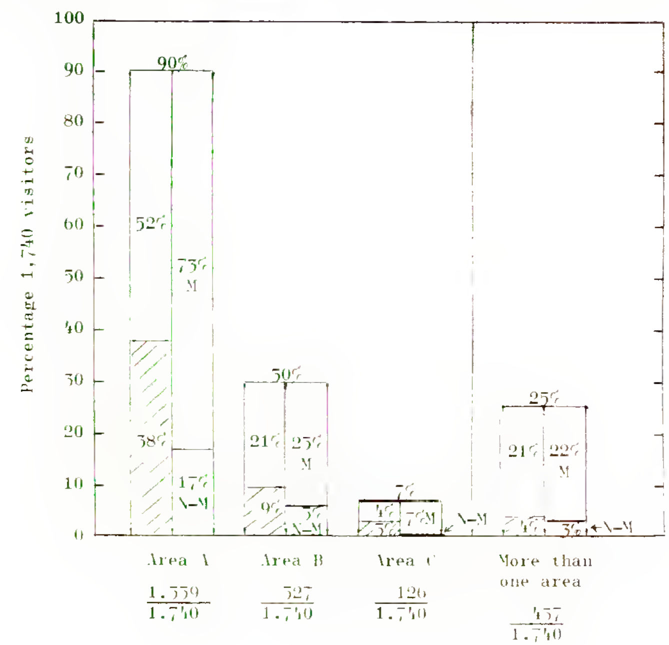


TABLE C6 — REEF AREAS VISITED– continued

Control Sample
Weeks I – V
May 30 – July 3

	SCHOOL Marin	SCHOOL Non-M	GENERAL Marin	GENERAL Non-M	GENERAL Unknown		%
Area A only	654	331	283	256	263	1,787	70.4
Areas A+B	146	166	53	–	–	365	14.4
Area B only	11	–	104	74	54	243	9.6
Areas B+C	–	–	3	–	–	3	0.1
Area C only	37	8	32	6	30	113	4.4
Areas A,B,C	27	–	–	–	–	27	1.1
	875	505	475	336	347	2,538	100.0%

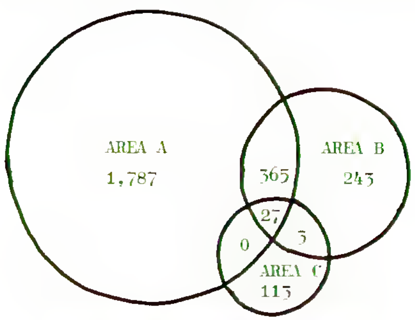


CHART C6 — COMPARISON OF SCHOOL AND GENERAL VISITS IN EACH AREA

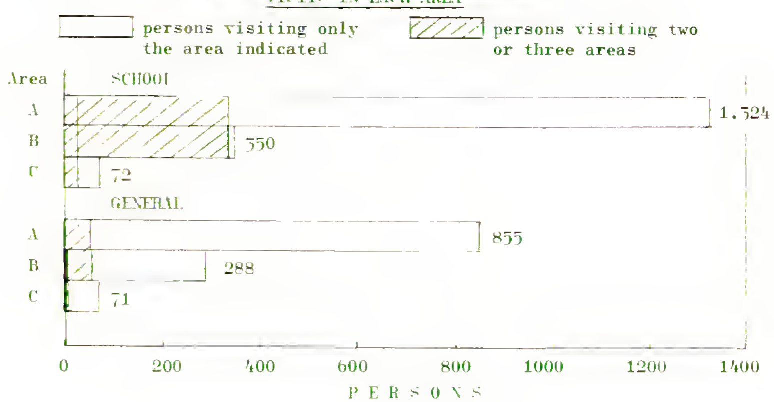


TABLE T6 — REEF AREAS VISITED– continued

Treatment Sample
Weeks VI – X
July 4 – August 7

	SCHOOL Marin	SCHOOL Non-M	GENERAL Marin	GENERAL Non-M		%
Area A only	511	36	377	198	1,122	64.5
Areas A+B	289	40	51	22	402	23.1
Area B only	3	3	49	35	90	5.2
Areas B+C	–	–	–	–	0	–
Area C only	44	–	47	–	91	5.2
Areas A,B,C	33	–	–	2	35	2.0
	880	79	524	257	1,740	100.0%

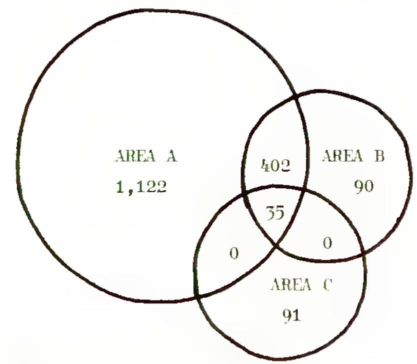


CHART T6 — COMPARISON OF SCHOOL AND GENERAL VISITS IN EACH AREA

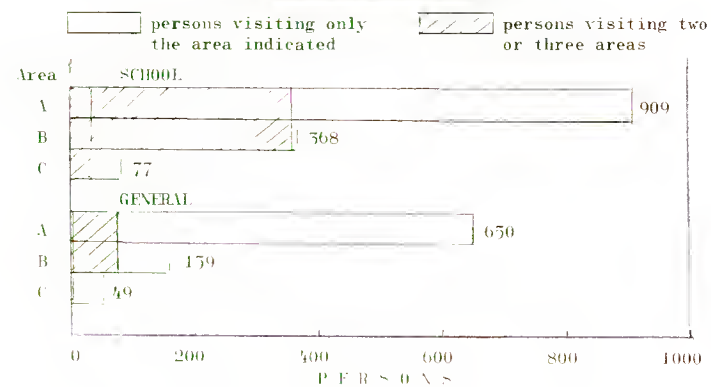


TABLE C7

ACTIVITY ON THE REEF

Control Sample
Weeks I – V
May 30 – July 3

Group **2c** (collectors of other reef components)
collects shells, algae, rocks (agates), driftwood, glass.

ACTIVITY	All Visitors	School	General	Marin	Non-Marin	Unknown
1. FISHERMEN	193 7.6%	– –	193 16.7%	112 8.3%	54 6.4%	27 7.8%
2. COLLECTORS						
a– Rock clams (fishermen)	37 1.5%	– –	37 3.2%	22 1.6%	5 0.6%	10 2.9%
b– Organisms (living animals)	671 26.4%	370 26.8%	301 26.0%	271 20.1%	264 31.4%	136 39.2%
c– Other	333 13.1%	198 14.3%	135 11.7%	223 16.5%	105 12.5%	5 1.4%
d– Unknown*	452 17.8%	331 24.0%	121 10.4%	297 22.0%	89 10.6%	66 19.0%
	1,493 58.8%	899 65.1%	594 51.3%	813 60.2%	463 55.1%	217 62.5%
3. NON–COLLECTORS	852 33.6%	481 34.9%	371 32.0%	425 31.5%	324 38.5%	103 29.7%
TOTALS	2,538 100.0%	1,380 100.0%	1,158 100.0%	1,350 100.0%	841 100.0%	347 100.0%

*collectors of unknown numbers of organisms, plant and animal
Note: 25 fishermen who removed living organisms from the reef for use as fish bait are counted as collectors.

GRAPH C7

COMPARISON OF ACTIVITY BY PERCENTAGE

F= Fishermen
C= Collectors
NC= Non–Collectors

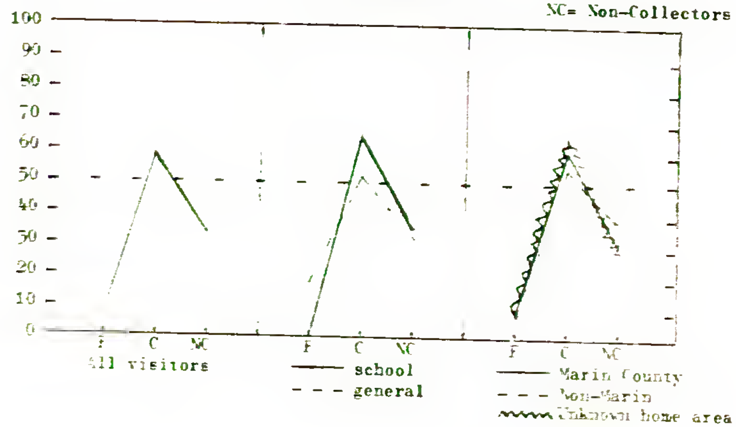


TABLE T7

ACTIVITY ON THE REEF

Treatment Sample
Weeks VI – X
July 4 – August 7

Group **2c** (collectors of other reef components)
collects shells, algae, rocks (agates), driftwood, glass.

ACTIVITY	All Visitors	School	General	Marin	Non-Marin
1. FISHERMEN	193 11.1%	– –	193 24.7%	151 10.8%	42 12.5%
2. COLLECTORS					
a– Clams (fishermen)	0	–	–	–	–
b– Living marine animals	205 11.8%	153 16.0%	52 6.7%	156 11.1%	49 14.6%
c– Other	98 5.6%	– –	98 12.5%	29 2.1%	69 20.5%
d– Unknown*	73 4.2%	33 3.4%	40 5.1%	61 4.3%	12 3.6%
	376 21.6%	186 19.4%	190 24.3%	246 17.5%	130 38.7%
3. NON–COLLECTORS	1,171 67.3%	773 80.6%	398 51.0%	1,007 71.7%	164 48.8%
TOTALS	1,740 100.0%	959 100.0%	781 100.0%	1,404 100.0%	336 100.0%

*collectors of unknown numbers of organisms, plant and animal
Note: 26 fishermen who removed living organisms from the reef for use as fish bait are counted as collectors.

GRAPH T7

COMPARISON OF ACTIVITY BY PERCENTAGE

F= Fishermen
C= Collectors
NC= Non–Collectors

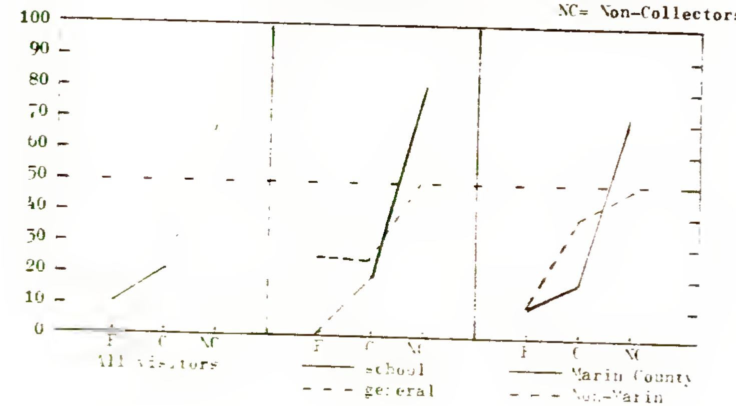


TABLE C8 — ACTIVITY ON EACH REEF AREA — Control Sample, Weeks I – V, May 30 – July 3

Activity	AREA A Sch	AREA A Gen	AREA B Sch	AREA B Gen	AREA C Sch	AREA C Gen	AREA TOTALS A	AREA TOTALS B	AREA TOTALS C	memo (D)
1. FISHERMEN	–	126	–	44	–	23	126	44	23	(–)
2. COLLECTORS										
a– Clams (fishermen)	–	24	–	0	–	4	24	9	4	(227)
b– Living marine animals	256	234	115	60	10	7	490	175	17	(–)
c– Other	261	85	33	50	–	–	346	83	–	(20)
d– Unknown*	322	65	16	32	11	26	387	48	37	(10)
total	(839)	(408)	(164)	(151)	(21)	(37)	(1247)	(315)	(58)	(257)
3. NON-COLLECTORS	485+	321	186	93	51	11	806	279	62	(–)
Totals	1324	855	350	288	72	71	2179	638	143	(257)

* collectors of unknown numbers of organisms, plant and animal

+75 non-collectors caused great displacement of living animals

CHART C8 — COMPARISON OF SCHOOL AND GENERAL ACTIVITY IN EACH AREA

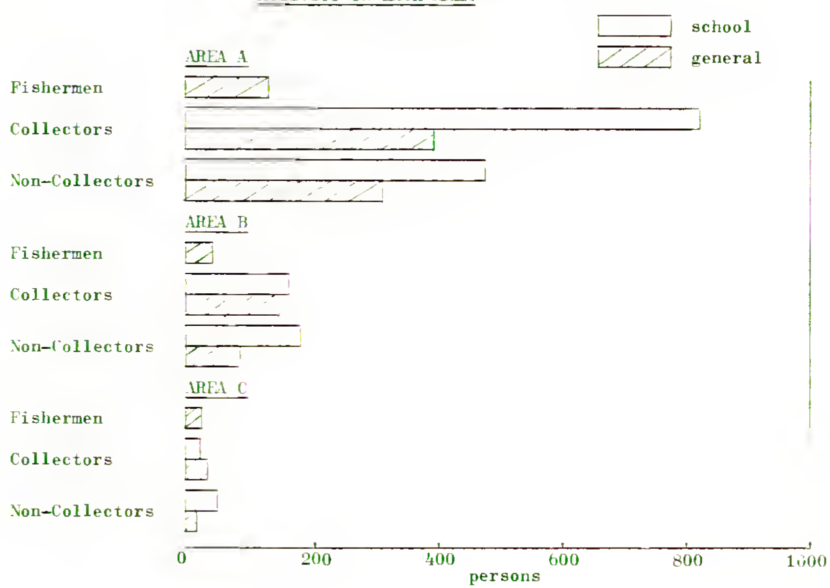


TABLE T8 — ACTIVITY ON EACH REEF AREA — Treatment Sample, Weeks VI – X, July 4 – August 7

Activity	AREA A Sch	AREA A Gen	AREA B Sch	AREA B Gen	AREA C Sch	AREA C Gen	AREA TOTALS A	AREA TOTALS B	AREA TOTALS C
1. FISHERMEN	–	125	–	41	–	34	125	41	34
2. COLLECTORS									
a– Clams (fishermen)	–	–	–	–	–	–	–	–	–
b– Living marine animals	81	24	13	23	59	5	105	36	64
c– Other	–	98	–	10	–	–	98	10	–
d– Unknown*	40	34	23	6	–	–	74	29	–
total	(121)	(156)	(36)	(39)	(59)	(5)	(277)	(75)	(64)
3. NON-COLLECTORS	788+	369	332	79	18	10	1157	411	28
Totals	909	650	368	159	77	49	1559	527	126

* collectors of unknown numbers of organisms, plant and animal

+ 100 non collectors subjected to "salted" or hand placed marine organisms

CHART T8 — COMPARISON OF SCHOOL AND GENERAL ACTIVITY IN EACH AREA

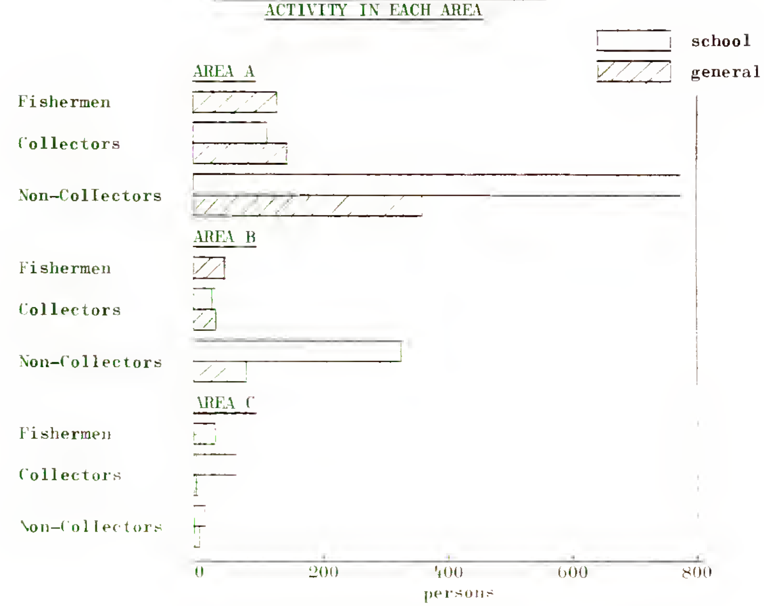


TABLE C9 — NUMBER OF LIVING MARINE ANIMALS COLLECTED — Control Sample, Weeks I – V, May 30 – July 3

° = planted in the area

	Tegula funebralis (turban snail)	Platyodon cancellatus (rock clam)	various Crustacea* (crabs)	Acmaea spp. (limpets)	Mytilus californianus (mussel)	Mopalia mucosa (chiton)	various Nudibranchs** (seaslugs)	Pisaster ochraceus P. brevispinus (seastars)	Anthopleura xanthogrammica (anemone)	Strongylocentrotus purpuratus (urchin)	Other***	TOTALS
AREA A												
Marin School	246	-	140	5	20	16	-	2	11	-	-	440
Non-Marin Sch	723	-	71	-	-	32	-	2°	-	2	18	848
SCHOOL Total	969	-	211	5	20	48	-	4	11	2	18	1288
Marin General	505	1811	37	200	-	23	-	2	11	10	-	2599
Non-Marin Gen	2656	10	41	-	200	20	-	5	5	-	1	2938
Unknown Gen	860	500	10	-	-	10	-	1	-	-	-	1381
GENERAL Total	4021	2321	88	200	200	53	-	8	16	10	1	6918
AREA A TOTALS	4990	2321	299	205	220	121	-	12	27	12	19	8206 =75%
AREA B												
Marin School	15	10	15	20	10	15	10	10	-	-	5	110
Non-Marin Sch	29	25	29	50	20	28	28	25	-	6	21	261
SCHOOL Total	44	35	44	70	30	43	38	35	-	6	26	371
Marin General	-	-	10	-	-	21	-	2	-	-	-	33
Non-Marin Gen	92	300	42	7	2	14	-	2	2	-	30	491
Unknown Gen	1000	500	-	-	20	-	-	-	-	10	-	1530
GENERAL Total	1092	800	52	7	22	35	-	4	2	10	30	2054
AREA B TOTALS	1136	835	96	77	52	78	38	39	2	16	56	2425 =22%
AREA C												
Marin School	-	-	-	-	-	-	17	-	-	-	-	17
Non-Marin Sch	-	-	-	-	-	-	-	-	-	-	-	-
SCHOOL Total	-	-	-	-	-	-	17	-	-	-	-	17
Marin General	-	300	-	-	-	-	10	-	-	-	-	310
Non-Marin Gen	-	-	-	-	8	6	-	-	-	-	-	14
Unknown Gen	-	-	-	-	-	-	-	-	-	-	-	-
GENERAL Total	-	300	-	-	8	6	10	-	-	-	-	324
AREA C TOTALS	-	300	-	-	8	6	27	-	-	-	-	341 = 3%
TOTALS FOR ALL AREAS	6126	3456	395	282	280	185	65	51	29	28	73	10972 =100%

* Cancer antennarius, Pachygrapsus crassipes, Hemigrapsus oregonensis

** See appendix

*** 30 sculpins, 24 invertebrates, 12 tidepool fishes, 3 worms, 4 barnacles

TABLE T9 — NUMBER OF LIVING MARINE ANIMALS COLLECTED — Treatment Sample, Weeks VI – X, July 4 – August 7

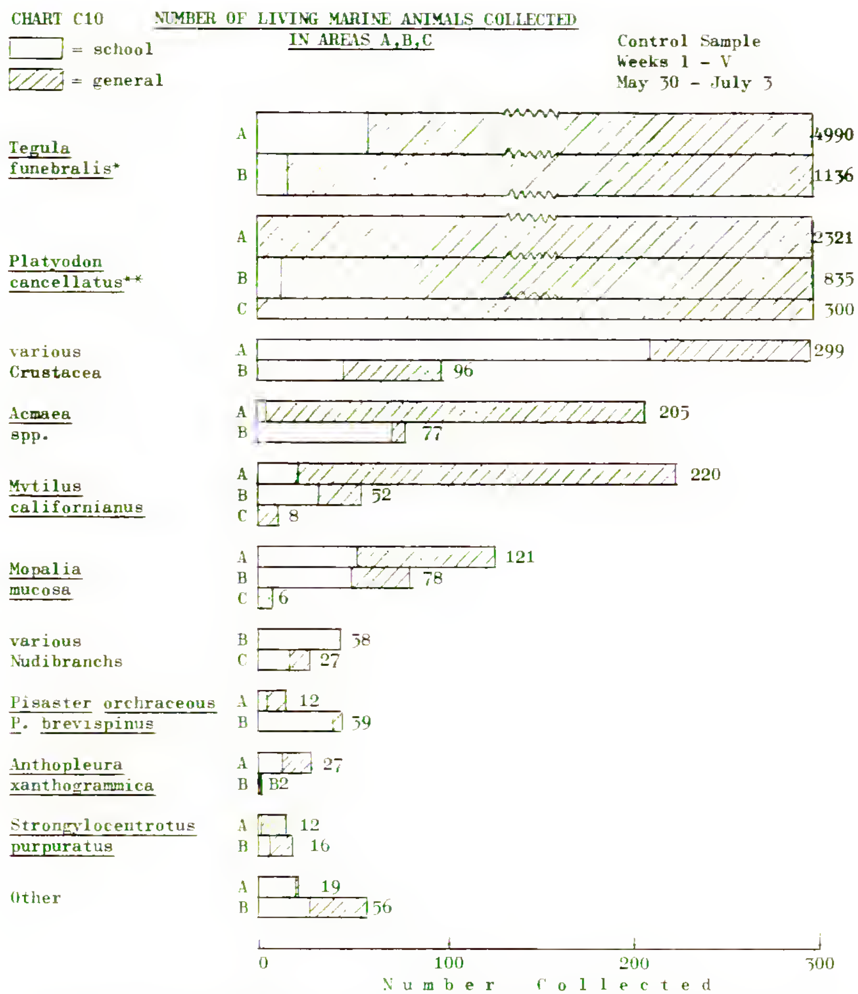
° = planted in the area

	Tegula funebralis (turban snail)	various Polychaetes (bristle worms)	various Crustacea* (crabs)	Mopalia mucosa (chiton)	Platyodon cancellatus (rock clam)	various Nudibranchs** (seaslugs)	Strongylocentrotus purpuratus (urchin)	Anthopleura xanthogrammica (anemone)	Mytilus californianus (mussel)	Pisaster orchraceus P. brevispinus (seastars)	Acmaea spp. (limpets)	Other***	TOTAL
AREA A													
Marin School	35	-	43	-	-	1	-	-	-	-	-	11	90
Non-Marin Sch	10	-	15	5	-	5	5	-	-	5	5	-	50
SCHOOL Total	45	-	58	5	-	6	5	-	-	5	5	11	140
Marin General	11	-	21	8	-	-	-	-	-	2	-	-	42
Non-Marin Gen	28	-	7	-	-	-	-	-	-	1°	-	-	36
GENERAL Total	39	-	28	8	-	-	-	-	-	3	-	-	78
AREA A TOTALS	84	-	86	13	-	6	5	-	-	8	5	11	218= 24%
AREA B													
Marin School	5	-	15	-	-	-	-	-	-	-	5	-	25
Non-Marin Sch	-	-	-	-	-	-	-	-	-	-	-	-	-
SCHOOL Total	5	-	15	-	-	-	-	-	-	-	5	-	25
Marin General	-	-	3	-	-	-	-	-	-	-	-	-	3
Non-Marin Gen	250	133	-	34	50	-	-	-	-	-	-	-	467
GENERAL Total	250	133	3	34	50	-	-	-	-	-	-	-	470
AREA B TOTALS	255	133	18	34	50	-	-	-	-	-	5	-	495= 56%
AREA C													
Marin School	19	2	24	16	2	18	32	16	16	7	-	2	154
Non-Marin Sch	-	(no visitors in this area)						-	-	-	-	-	-
SCHOOL Total	19	2	24	16	2	18	32	16	16	7	-	2	154
Marin General	-	1	-	-	-	26	-	-	-	-	-	-	27
Non-Marin Gen	-	(only 2 visitors in this area)						-	-	-	-	-	-
GENERAL Total	-	1	-	-	-	26	-	-	-	-	-	-	27
AREA C TOTALS	19	3	24	16	2	44	32	16	16	7	-	2	181= 20%
TOTALS FOR ALL AREA	358	136	128	63	52	50	37	16	16	15	10	13	894=100%

* Cancer antennarius, Pachygrapsus crassipes, Hemigrapsus oregonensis (crabs)

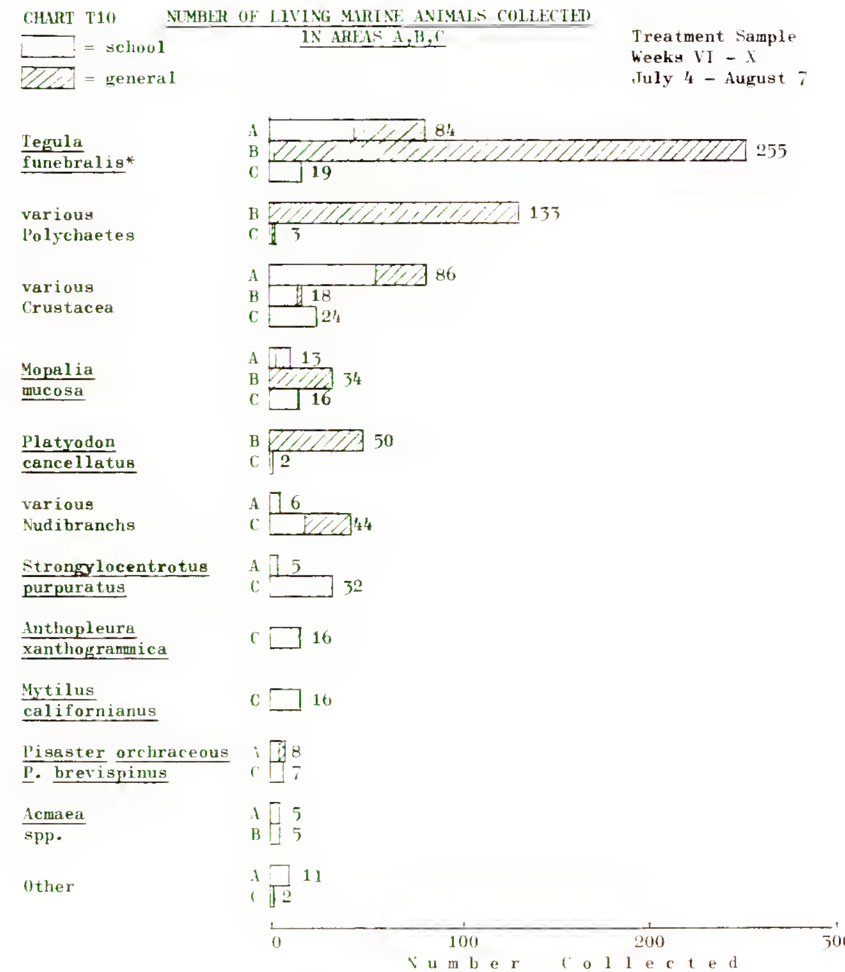
** See appendix

*** 11 tidepool fishes, 2 sponges



* Collectors of a minimum of 50 Tegula (black turban snails) each:
Area A-15 collectors = 3,550 Tegula
B- 3 collectors = 1,000 Tegula
C-no collectors
18 collectors = 4,550 Tegula

** Collectors of a minimum of 50 Platyodon (rock clams) each:
Area A-24 collectors = 1,810 Platy
B- 9 collectors = 1,100 Platy
C- 4 collectors = 300 Platy
37 collectors = 3,210 Platy



* Collectors of a minimum of 50 Tegula (black turban snails) each:
Area A – 2 collectors for total of 200 Tegula
B – no collectors
C – no collectors
2 collectors = 200 Tegula

TABLE C11

OBSERVED COLLECTORS OF LIVING MARINE ANIMALS

Control Sample
Weeks I – V
May 30 – July 3

KEY:

Tegula= collectors of a minimum of 50 Tegula funebralis (black turban snails)
Platyodon= collectors*of a minimum of 50 Platyodon cancellatus (rock clams)
Other= collectors of less than 50 each of the above and other species.

*clam fishermen

Note: There were no school visitors collecting 50 or more Platyodon collector.

NUMBER OF COLLECTORS

	School		General			
	Teg-ula	Other	Teg-ula	Plat-yodon	Other	
Marin	–	210	2	22	59	293
Non-Marin	6	154	2	5	102	269
Unknown	–	–	8	10	128	146
	6	364	12	37	289	708 collectors
	(370)		(338)			

NUMBER OF ANIMALS COLLECTED

	School		General			
	Teg-ula	Other	Teg-ula	Plat-yodon	Other	
Marin	–	567	400	2110	432	3509
Non-Marin	300	809	2500	300	643	4552
Unknown	–	–	1350	1000	561	2911
	300	1376	4250	3410	1656	10972 animals
	(1676)		(9296)			

AVERAGE NUMBER COLLECTED/COLLECTOR

	School		General			
	Tegula	Other	Tegula	Platyodon	Other	
Marin	–	2.7	200.0	95.9	7.3	12.0
Non-Marin	50.0	5.3	1250.0	60.0	6.5	16.9
Unknown	–	–	168.8	100.0	4.4	19.9
	50.0	3.8	354.2	92.2	5.7	15.5 animals per collector
	(4.5 animals)		(27.5 animals)			

PERCENTAGE OF COLLECTORS

	School		General			
	Teg-ula	Other	Teg-ula	Plat-yodon	Other	
Marin	–	29.7	0.3	3.1	8.3	41.4
Non-Marin	0.8	21.8	0.3	0.7	14.4	38.0
Unknown	–	–	1.1	1.4	18.1	20.6
	0.8	51.5	1.7	5.2	40.8	100.0%
	(52.3%)		(47.7%)			

PERCENTAGE OF ANIMALS COLLECTED

	School		General			
	Teg-ula	Other	Teg-ula	Plat-yodon	Other	
Marin	–	5.2	3.6	19.3	3.9	32.0
Non-Marin	2.7	7.4	22.8	2.7	5.9	41.5
Unknown	–	–	12.3	9.1	5.1	26.5
	2.7	12.6	38.6	31.1	14.9	100.0%
	(15.3%)		(84.7%)			

TABLE T11

OBSERVED COLLECTORS OF LIVING MARINE ANIMALS

Treatment Sample
Weeks VI – X
July 4 – August 7

KEY:

Tegula= collectors of a minimum of 50 Tegula funebralis (black turban snails)
Other= collectors of less than 50 each of Tegula and other species

Note: There were no Platyodon cancellatus (rock clam) fishermen observed.

There were no school visitors collecting 50 or more Tegula collector.

NUMBER OF COLLECTORS

	School	General		
	Other	Tegula	Other	
Marin	129	–	27	156
Non-Marin	24	2	23	49
	153	2	50	205 collectors
	(153)	(52)		

NUMBER OF ANIMALS COLLECTED

	School	General		
	Other	Tegula	Other	
Marin	269	–	72	341
Non-Marin	50	200	303	553
	319	200	375	894 animals
	(319)	(575)		

AVERAGE NUMBER COLLECTED/COLLECTOR

	School	General		
	Other	Tegula	Other	
Marin	2.1	–	2.7	2.2
Non-Marin	2.1	100.0	13.2	11.3
	2.1	100.0	7.5	4.4 animals per collector
	(2.1)	(11.1)		

PERCENTAGE OF COLLECTORS

	School	General		
	Other	Tegula	Other	
Marin	62.9	–	13.2	76.1
Non-Marin	11.7	1.0	11.2	23.9
	74.6	1.0	24.4	100.0%
	(74.6)	(25.4)		

PERCENTAGE OF ANIMALS COLLECTED

	School	General		
	Other	Tegula	Other	
Marin	30.1	–	8.0	38.1
Non-Marin	5.6	22.4	33.9	61.9
	35.7	22.4	41.9	100.0%
	(35.7)	(64.3)		

TABLE C12

SCHOOL VISITORS

(Elementary, Secondary, College)

Control Sample
Weeks I – V
May 30 – July 3

Note: Out of a total of 1,083 elementary school visitors, (214) were accompanied by a Bolinas Marine Station staff member. This latter group is represented below in parentheses.

Number in School Group		AREAS VISITED: A only	A + B	B only	C only	A,B,C
1,083 Elementary(214)	78%	864(181)	202(33)	–	17	–
175 Secondary	15%	109	33	11	20	–
122 College	9%	12	73	–	8	27
1,380 Total	100%	985	312	11	45	27

ACTIVITY ON THE REEF

Number in School Group	Collectors: Living Marine Animals		Other Reef Components	Unknown Quantity	NON-collectors	Observed Animals Collected
1,083 Elementary(214)	249(20)	67%	188(30)	315(4)	331(160)	1,266(30)
175 Secondary	46	13%	–	–	129	278
122 College	75	20%	10	16	21	132
1,380 Total	370	100%	198	331	481	1,676
(Activity According to the Area)						
AREA A						
1,066 Elementary(214)	239(20)	93%	188(30)	308(4)	331(160)	1,243(30)
144 Secondary	5	2%	20	10	109*	8
114 College	12	5%	53	4	45	37
1,324 Total	256	100%	261	322	485	1,288
*73 students caused great displacement of organisms						
AREA B						
202 Elementary(33)	6	5%	33	–	163(33)	6
46 Secondary	46	40%	–	–	–	270
102 College	63	55%	–	16	23	95
350 Total	115	100%	33	16	186	371
AREA C						
17 Elementary	10	100%	–	7	–	17
20 Secondary	–		–	–	20	none
35 College	–		–	4	31	none
72 Total	10	100%	–	11	51	17

OBSERVED ANIMALS COLLECTED

Area A

Elementary: 966 Tegula, 204 Crustacea, 46 Mopalia, 4 Pisaster, 3 Anthopleura, 18 invertebrates = 1,243 total

Secondary: 3 Tegula, 1 Crustacea, 2 Mopalia, 2 Strongylocentrotus = 8 total

College: 6 Crustacea, 3 Acmaea, 20 Mytilus, 6 Anthopleura = 37 total

Area B

Elementary: 6 invertebrates = 6 total

Secondary: 34 Tegula, 20 Platyodon, 29 Crustacea, 30 Acmaea, 30 Mytilus, 33 Mopalia, 28 Nudibranch, 25 Pisaster, 6 Strongylocentrotus, 4 Balanus, 11 Sculpin = 270 total

College: 10 Tegula, 13 Playtodon, 13 Crustacea, 20 Acmaea, 10 Mopalia, 10 Nudibranch, 10 Pisaster, 3 Polychaete = 95 total

Area C

Elementary: 17 Nudibranch = 17 total

TABLE T12

SCHOOL VISITORS

(Elementary, Secondary, College)

Treatment Sample
Weeks VI – X
July 4 – August 7

Note: Out of a total of 684 elementary and 140 secondary school visitors, (129) elementary and (32) secondary visitors were accompanied by a Bolinas Marine Station staff member. The figures in parentheses below represent these BMS visitor groups.

Number in School Group		AREAS VISITED: A only	A + B	B only	C only	A,B,C
684 Elementary(129)	71%	345	329(129)	–	10	–
140 Secondary (32)	15%	82	–	–	26	32(32)
135 College	14%	120	–	6	8	1
959 Total	100%	547	329	6	44	33

ACTIVITY ON THE REEF

Number in School Group	Collectors: Living Marine Animals		Other Reef Components	Unknown Quantity	NON-collectors	Observed Animals Collected
684 Elementary(129)	60	39%	–	30	594(129)	101
140 Secondary(32)	58(32)	38%	–	–	82	151
135 College	35	23%	–	3	97	67
959 Total	153	100%	–	33	773	319
(Activity According to the Area)						
AREA A						
674 Elementary(129)	50	62%	–	40	584*(129)	86
114 Secondary (32)	–	–	–	–	114(32)	none
121 College	31	38%	–	–	90	54
909 Total	81	100%	–	40	788	140
*A salted Crustacea was "picked up" 40 or more times until death by a group of 83 students; these same students picked up a salted Pisaster at least 50 times.						
AREA B						
329 Elementary(129)	10	77%	–	20	299(129)	15
32 Secondary (32)	–	–	–	–	32(32)	none
7 College	3	23%	–	3	1	10
368 Total	13	100%	–	23	332	25
AREA C						
10 Elementary	–	–	–	–	10	none
58 Secondary(32)	58(32)	98%	–	–	–	151(32)
9 College	1	2%	–	–	8	3
77 Total	59	100%	–	–	18	150

OBSERVED ANIMALS COLLECTED

Area A

Elementary: 40 Tegula, 46 Crustacea = 86 total

Secondary: none

College: 3 Tegula, 12 Crustacea, 3 Mopalia, 6 Nudibrach, 3 Strongylocentrotus, 3 Pisaster, 3 Acmaea, 11 Sculpin = 54 total

Area B

Elementary: 3 Tegula, 10 Crustacea = 13 total

Secondary: none

College: 5 Crustacea, 5 Acmaea = 10 total

Area C

Elementary: none

Secondary: 16 Tegula, 2 Polychaete, 24 Crustacea, 16 Mopalia, 2 Platyodon, 18 Nudibranch, 52 Strongylocentrotus, 16 Anthopleura, 16 Mytilus, 7 Pisaster, 2 Porifera = 151 total

College: 3 Tegula = 3 total


CHART C13
SCHOOL VISITORS
(Elementary, Secondary, College)
Control Sample
Weeks I – V
May 30 – July 3
Scale: ½ inch= 100
BMS = school visitors accompanied by Bolinas Marine Station staff member
NUMBER of VISITORS
Elementary
Secondary
College
BMS
1083
175
122
ACTIVITY on the REEF
Elementary = 100%
Collectors
Non-collectors
BMS
752 = 69.4%
BMS
331 = 30.6%
Secondary = 100%
Collectors
Non-collectors
46 = 26.3%
129 = 73.7%
College = 100%
Collectors
Non-collectors
101 = 82.8%
21 = 17.2%
OBSERVED LIVING MARINE ANIMALS COLLECTED
BMS
AREA A
Secondary=8 (5 collectors)
College=37 (12 collectors)
Elementary=1243
(239 collectors)
AREA B
Elementary=6 (6 collectors)
Secondary=270 (46 collectors)
College=95 (63 collectors)
AREA C
Elementary=17 (10 collectors)
AVERAGE NUMBER of ANIMALS COLLECTED COLLECTOR
Elementary
Secondary
College
Overall Average
BMS
5.1
6.0
1.8
4.3
0
1
2
3
4
5
6
7
Average number of animals collected per collector

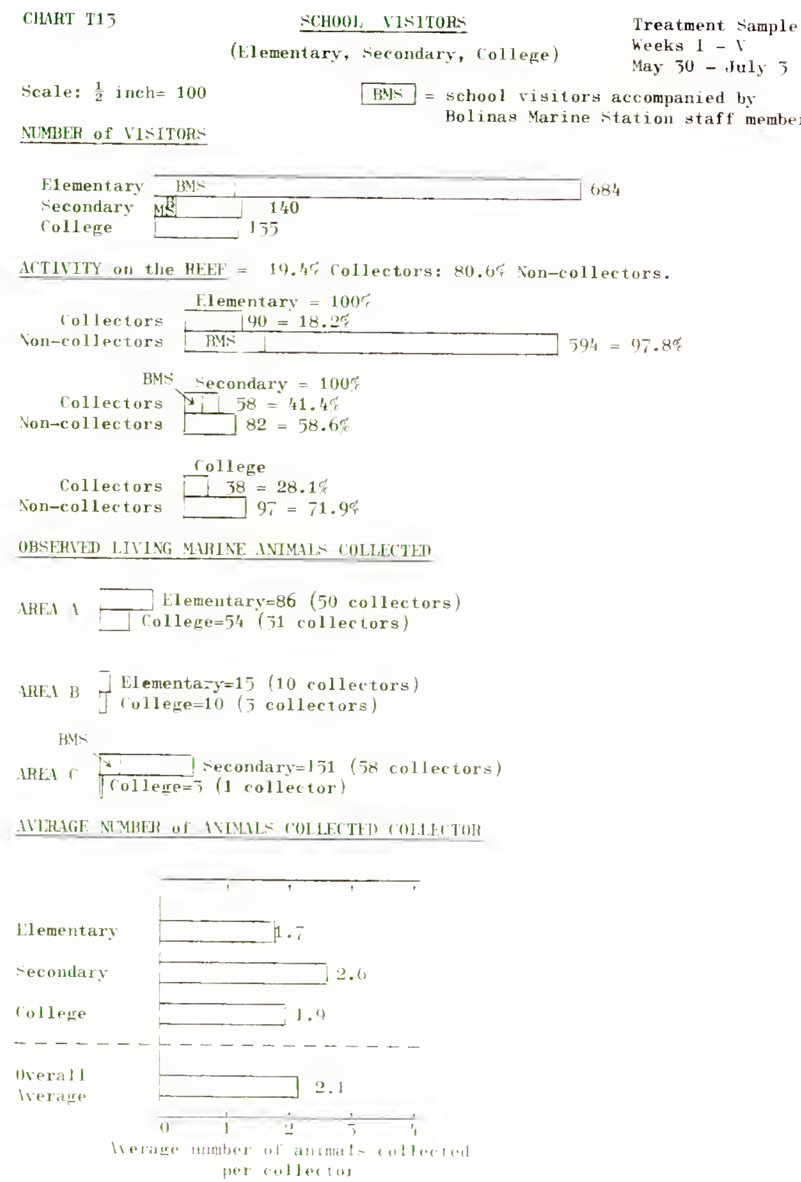


CHART T13
SCHOOL VISITORS
(Elementary, Secondary, College)
Treatment Sample
Weeks I – V
May 30 – July 3
Scale: ½ inch= 100
BMS = school visitors accompanied by Bolinas Marine Station staff member
NUMBER of VISITORS
Elementary
Secondary
College
BMS
684
MS
140
133
ACTIVITY on the REEF = 19.4% Collectors: 80.6% Non-collectors.
Elementary = 100%
Collectors
Non-collectors
90 = 18.2%
BMS
594 = 97.8%
BMS
Secondary = 100%
Collectors
Non-collectors
58 = 41.4%
82 = 58.6%
College
Collectors
Non-collectors
38 = 28.1%
97 = 71.9%
OBSERVED LIVING MARINE ANIMALS COLLECTED
AREA A
Elementary=86 (50 collectors)
College=54 (31 collectors)
AREA B
Elementary=15 (10 collectors)
College=10 (3 collectors)
BMS
AREA C
Secondary=151 (58 collectors)
College=3 (1 collector)
AVERAGE NUMBER of ANIMALS COLLECTED COLLECTOR
Elementary
Secondary
College
Overall Average
1.7
2.6
1.9
2.1
0
1
2
3
4
Average number of animals collected per collector

GRAPH CT14

SUMMARY COMPARISON OF NUMBER OF LIVING MARINE ANIMALS COLLECTED BY CONTROL AND TREATMENT SAMPLE VISITORS

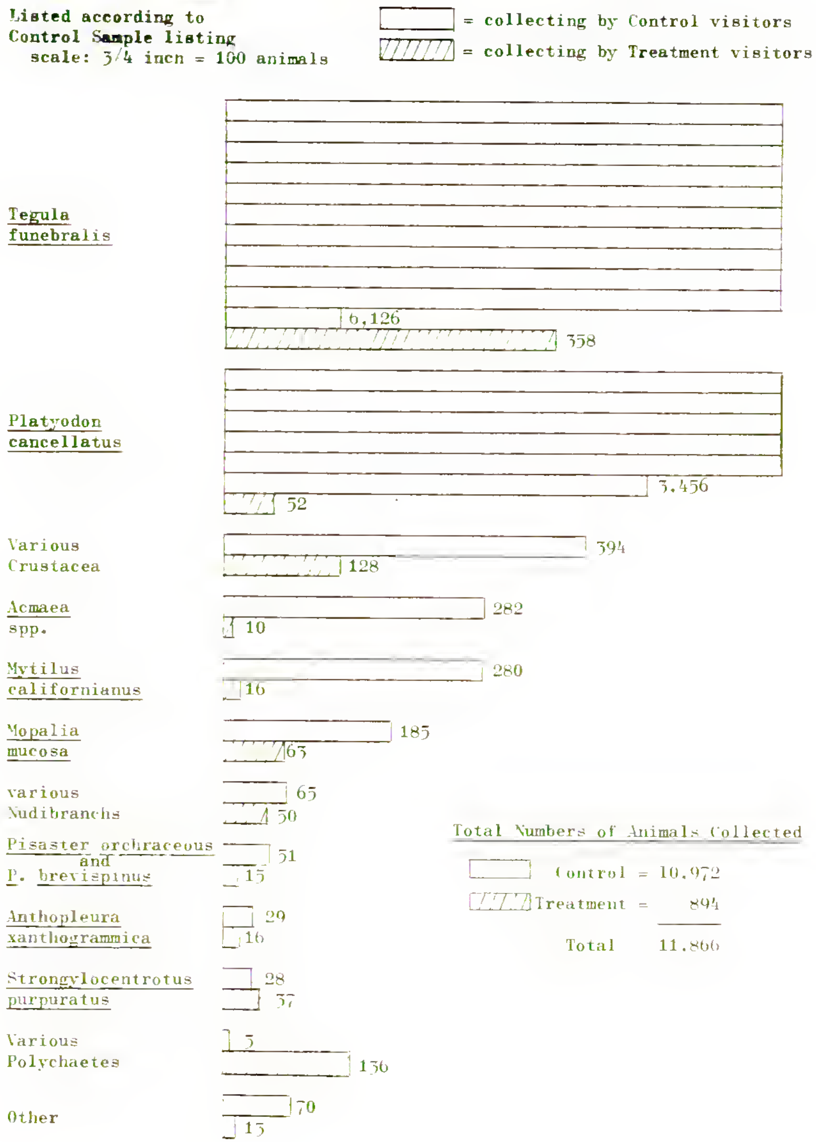


TABLE CT14

SUMMARY COMPARISON
of Control Sample and Treatment Sample
Weeks I – V / Weeks VI – X
May 30– July 3 / July 4– August 7

NUMBER OF REEF VISITORS

	Control	Treatment
School	1380 (54.4%)	959 (55.1%)
General	1158 (45.6%)	781 (44.9%)
	2538 (100.0%)	1740 (100.0%)
Avg./day	72 visitors	49 visitors

NUMBER OF COLLECTORS
(Collectors of plant, animal, rock)

	Control	Treatment
School	899	186
General	594	190
	1493	376

LIVING MARINE ANIMALS
(No. collected/No. of collectors)

	Control	Treatment
School	1676 370	319 155
General	9296 338	575 52
	10972 708	894 205

LIVING MARINE ANIMALS
(Average No. Collected per Collector)

	Control	Treatment
School	4.5	2.1
General	27.5	11.1
	15.5	4.4

D. BASE COUNT COMPARISONS

1. Table B1 Base Counts of Living Marine Aniamsl, page 59

Base counts were conducted on five transects, each ten meters long, taken in each area A, B, and C, for a total of fifteen transects. Animals were counted for each square meter measured along the ten linear meters of each transect, for a total of fifty square meters in each area. Base count dates were:

Base count 1	May 28 - 31
Base count 2	July 1 - 4
Base count 3	August 4 - 7

Table B1 records the total counted for each specific species of organisms for the five transects of each area. The table also shows the total number of animals counted and the average number of animals counted per square meter.

2. Graph B1 Comparison of Base Counts, page 60

This graph illustrates the average number of marine animals counted per square meter for each of the three base counts.

TABLE B1

BASE COUNTS
OF LIVING MARINE ANIMALS
(listed by area)

Counts were taken at each reef area A,B,C by taking 5 transects of 10 one-meter plots per transect, a total of 50 plots for each reef area.

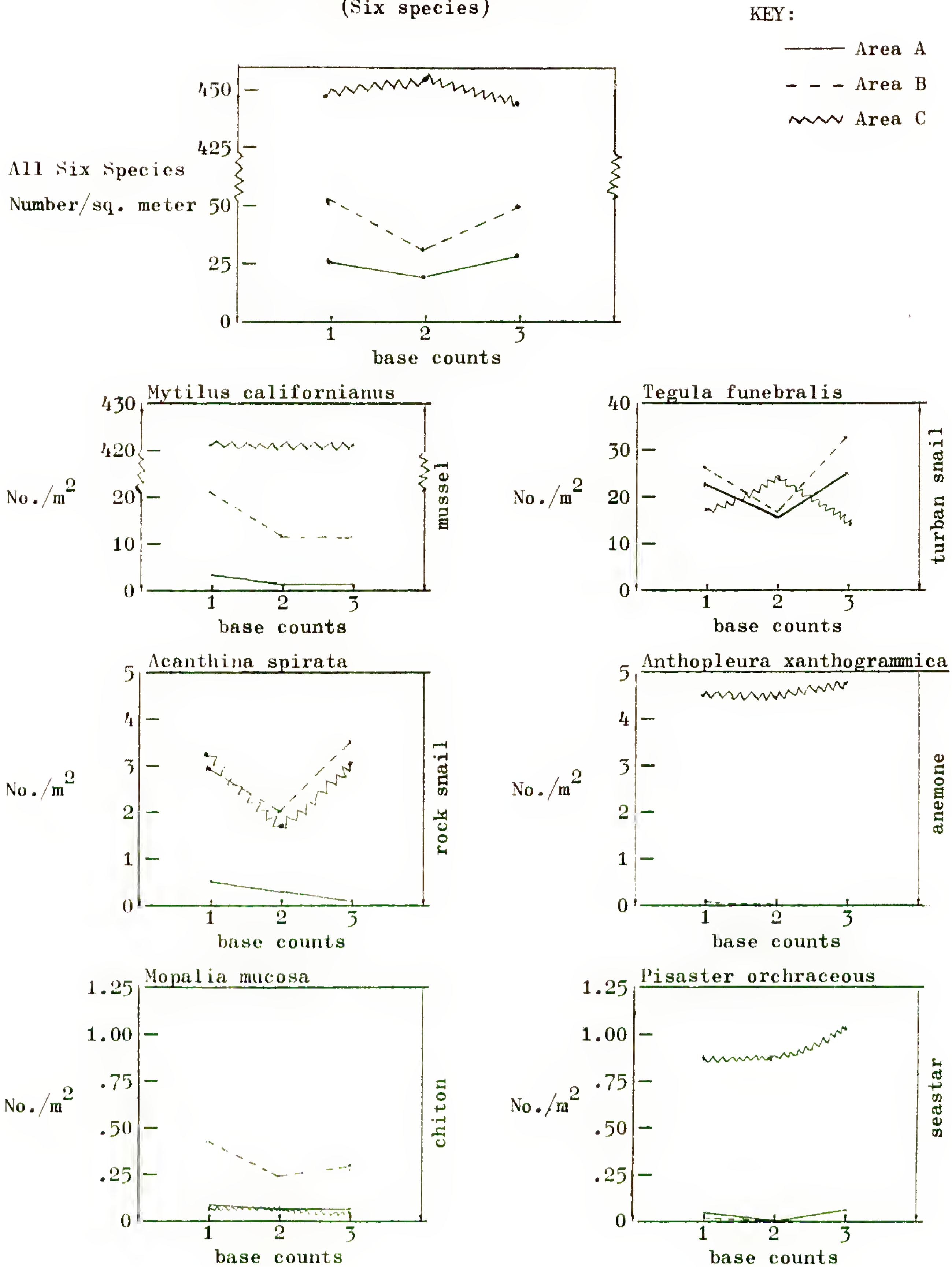
Count 1: May 28-31
Count 2: July 1-4
Count 3: August 4-7

AREA	BASE COUNT	Mytilus californianus (mussel)	Tegula funebralis (turban snail)	Acanthina spirata (rock snail)	Anthopleura xanthogrammica (anemone)	Mopalia mucosa (chiton)	Pisaster ochraceous (seastar)	Other Marine Animals*	TOTAL
NUMBER OF ANIMALS									
A	1	126	1,117	26	-	4	2	(2,821)	1,275
	2	82	782	16	-	3	-	(2,710)	883
	3	82	1,271	2	-	3	3	(2,593)	1,361
B	1	1,084	1,313	147	1	21	1	(4,116)	2,567
	2	612	808	100	-	12	-	(4,095)	1,532
	3	619	1,671	181	-	14	-	(4,095)	2,485
C	1	21,067	865	161	225	3	43	(2,002)	22,364
	2	21,067	1,277	84	225	3	41	(2,005)	22,697
	3	21,096	741	156	238	2	51	(2,002)	22,284
AVERAGE NUMBER PER SQUARE METER									(Average for six species)
A	1	2.5	22.3	0.52	-	0.08	0.04	(56.42)	25.50
	2	1.6	15.6	0.32	-	0.06	-	(54.20)	17.66
	3	1.6	25.4	0.04	-	0.06	0.06	(51.86)	27.22
B	1	21.7	26.3	2.94	0.02	0.42	0.02	(9.32)	51.34
	2	12.2	16.2	2.00	-	0.24	-	(8.90)	30.64
	3	12.4	33.4	3.62	-	0.28	-	(8.90)	49.70
C	1	421.3	17.3	3.22	4.50	0.06	0.86	(40.04)	447.28
	2	421.3	25.5	1.68	4.50	0.06	0.82	(40.10)	453.94
	3	421.9	14.8	3.12	4.76	0.04	1.02	(40.04)	445.68

*Other marine animals were tabulated in the base counts, but these were not considered as important as the six species above. These other animals were either too small to maintain an accurate count or appeared in few numbers. These species were: Acmaea spp.(limpets), Polycipes polymerus (goose barnacle), Littorina scutulata (periwinkle), Strongylocentrotus purpuratus (sea urchin), Cancer antennarius (rock crab), Balanus spp. (acorn barnacle), Tegula brunnea (brown turban), & Thais emarginata (rock Thais snail).

GRAPH B1 COMPARISON OF BASE COUNTS

Average Number per Square Meter
(Six species)



E. CONSERVATION TEST OBSERVATIONS OF SCHOOL GROUPS (Elementary, Secondary, and College)

Score: The test consisted of five questions relating to various aspects of conservation behavior. Each visiting school class was rated by percentage, up to 100% on each question, making a perfect total score of 500% for the five questions. 100% on a specific question indicates the entire class showed conservation response or behavior whereas 0% indicates none in the class showed such behavior. See Appendix I for the test form.

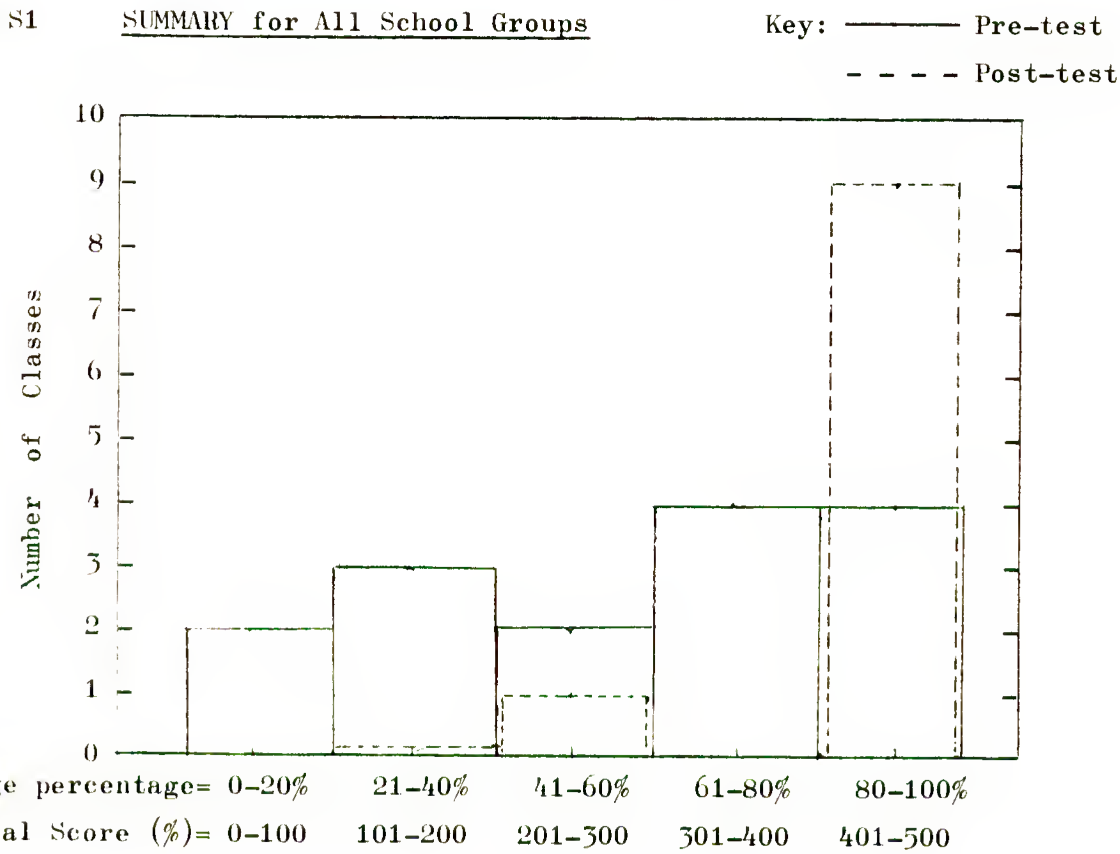
Two total scores were made by each class:

Pre-test score indicating response to the five-question test previous to conservation instruction by Bolinas Marine Station staff.

Post-test score indicating behavior on the reef relating to the same five-question test following conservation instruction.

Average Percentage: This percentage, obtained by dividing the total score by five, indicates the average proportion of the class showing conservation behavior.

GRAPH S1 SUMMARY for All School Groups



Overall scores for all school groups (15 classes = 709 school visitors):

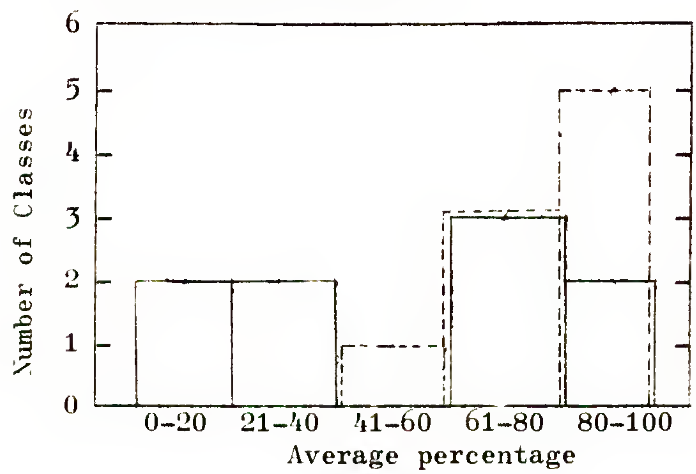
Average pre-test total score = 263.7; average percentage = 52.7%
Average post-test total score = 406.7; average percentage = 81.3%

GRAPH S2

CONSERVATION TEST OBSERVATIONS FOR EACH SCHOOL GROUP

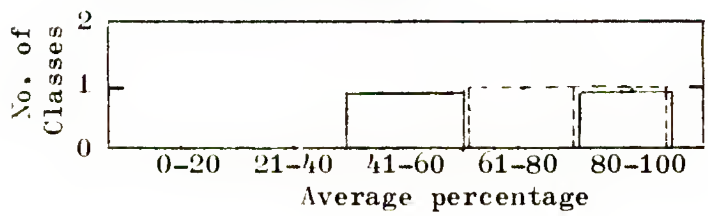
Key: ——— Pre-test
- - - Post-test

Elementary School Group



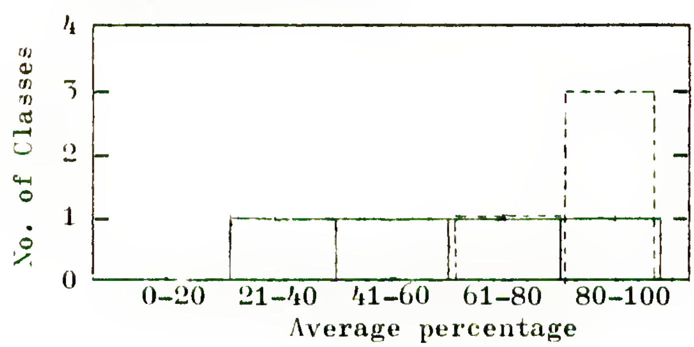
Overall elementary
group average percentage
for: Pre-test= 46.4%
Post-test= 79.8%

Secondary School Group



Overall secondary
group average percentage
for: Pre-test= 71.5%
Post-test= 80.5%

College School Group



Overall college
group average percentage
for: Pre-test= 57.5%
Post-test= 85.5%

TABLE S1 SCHOOL BEHAVIOR AVERAGE TEST SCORES FOR INDIVIDUAL QUESTIONS

School Behavior Test Items:

1. Do not collect living marine organisms.
2. If marine animal is picked up, replace it in its exact niche.
3. Turn the rock back over to its original position.
4. Do not tear up seaweed or rocky substrate to get at animals.
5. Walk carefully on the reef; disturb the least amount of marine life.

School Group	Mean Score	ASPECT OF CONSERVATION BEHAVIOR Test Item 1	2	3	4	5	TOTAL	AVERAGE TEST SCORE
Elementary (9 classes, 547 students)	Pre-test	43	43	46	57	43	232	46
	Post-test	74	71	76	96	83	400	80
	Gain	31	28	30	39	40	168	34
Secondary (2 classes, 48 students)	Pre-test	85	65	60	73	75	358	72
	Post-test	45	70	95	98	95	403	81
	Gain	-40	5	35	25	20	45	9
College (4 classes, 124 students)	Pre-test	76	64	58	44	46	288	58
	Post-test	85	86	85	83	79	418	85
	Gain	9	22	27	39	33	130	27
All Groups (15 classes, 719 students)	Pre-test	58	51	51	56	48	264	53
	Post-test	72	75	81	92	83	404	81
	Gain	15	24	30	36	35	140	28

F. CORRELATION AND COMPARISON OF REEF VISITORS

The summary charts illustrate the following:

1. Chart S1 Correlation of School Collectors and Numbers of Animals Collected per Year (1961–July, 1969), page 65

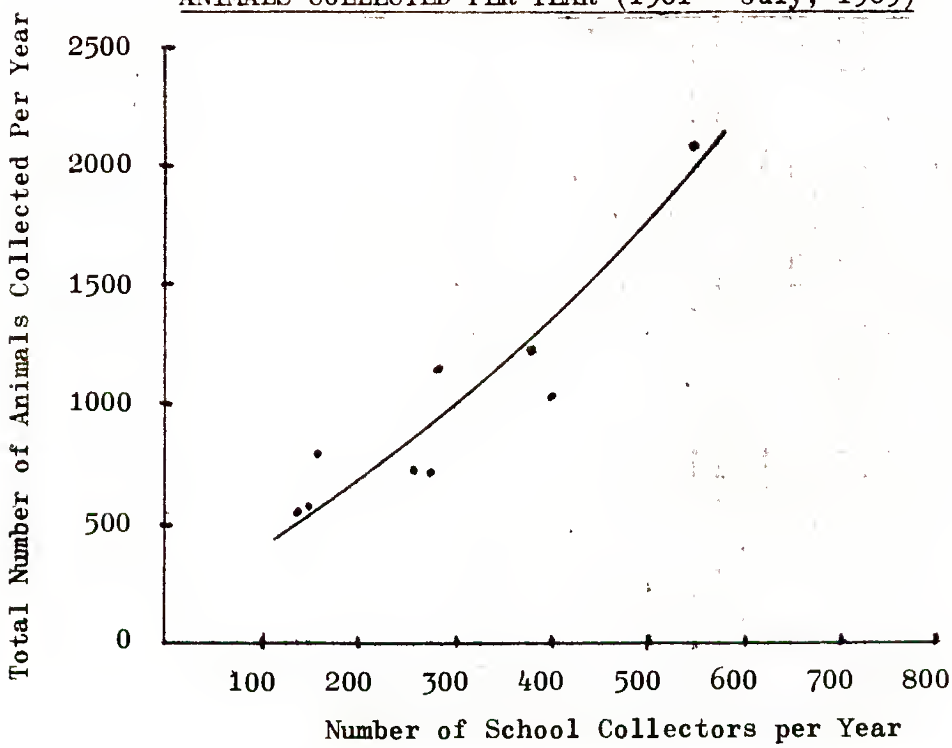
2. Chart S2 Comparison of Control and Treatment Correlations of Collectors on Reef and Number of Animals Collected per Week (May 30–August 7, 1969), page 65

3. Chart S3 Correlation of Conservation Education to the Collecting Behavior of General and School Visitors, page 66

   a. Correlation of Conservation Education to the Percentage of Visitors Who Collect (animals, plants, rocks), General Public and School Visitors

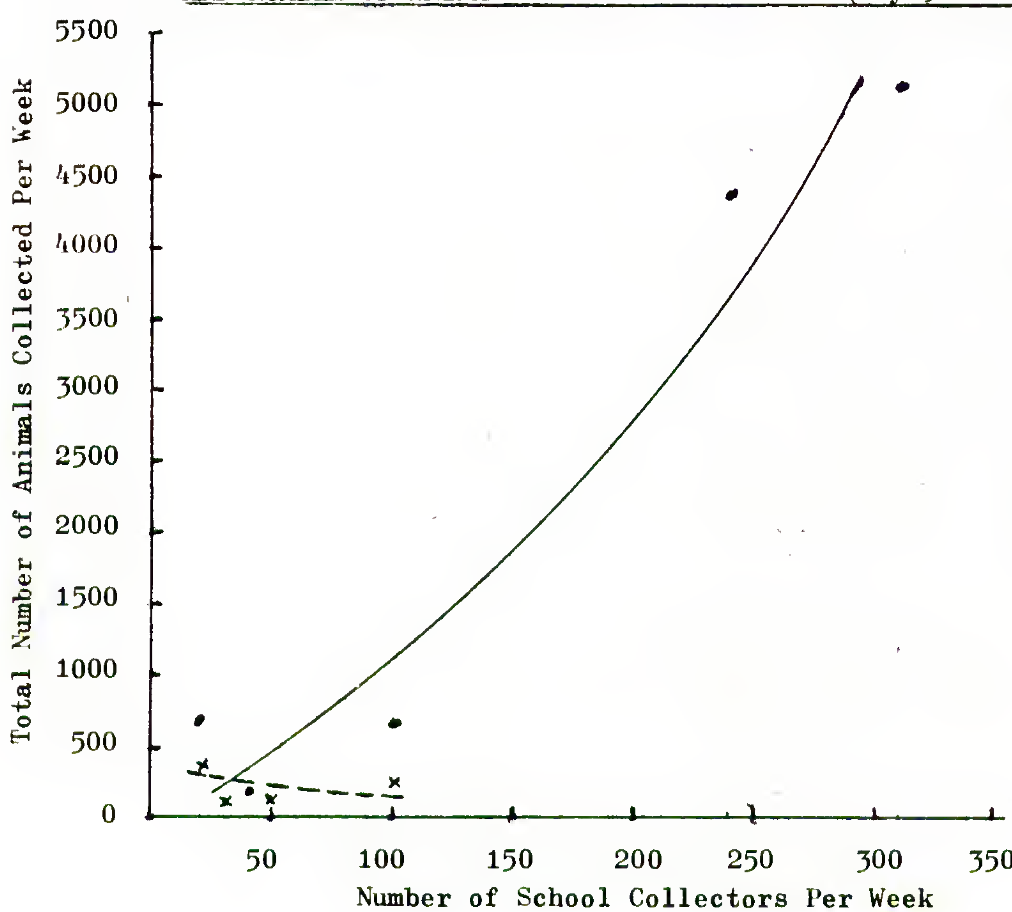
   b. Correlation of Conservation Education to the Average Number of Living Marine Animals Collected per Collector

CHART S1 CORRELATION OF SCHOOL COLLECTORS AND NUMBER OF ANIMALS COLLECTED PER YEAR (1961 - July, 1969)



Year	No. of Students	No. of Animals
1961	135	557
1962	147	580
1963	156	804
1964	285	1,141
1965	377	1,226
1966	232	731
1967	275	711
1968	402	1,023
1969	556	2,112

CHART S2 COMPARISON OF CONTROL AND TREATMENT CORRELATIONS OF COLLECTORS ON REEF AND NUMBER OF ANIMALS COLLECTED PER WEEK (May 30 - August 7, 1969)



	No. of Collectors	No. of Animals
•——• Control correlation		
I	308	5,154
II	101	636
III	19	655
IV	43	138
V	237	4,389
x– – –x Treatment correlation		
VI	23	476
VII	50	85
VIII	31	85
IX	101	248
X	0	0

CHART S3

CORRELATION OF CONSERVATION EDUCATION TO THE COLLECTING BEHAVIOR OF GENERAL AND SCHOOL VISITORS

Key for amount of conservation education:

●———● school visitors
x = control sample, no conservation education
y = control sample, directed by Bolinas Marine Station
z = treatment sample, with conservation education

x- - -x general visitors
a = control sample, no conservation education
b = treatment sample, with conservation education

CHART S3a

Correlation of Conservation Education to the Percentage of Visitors Who Collect (animals, plants, rocks), General Public and School Groups

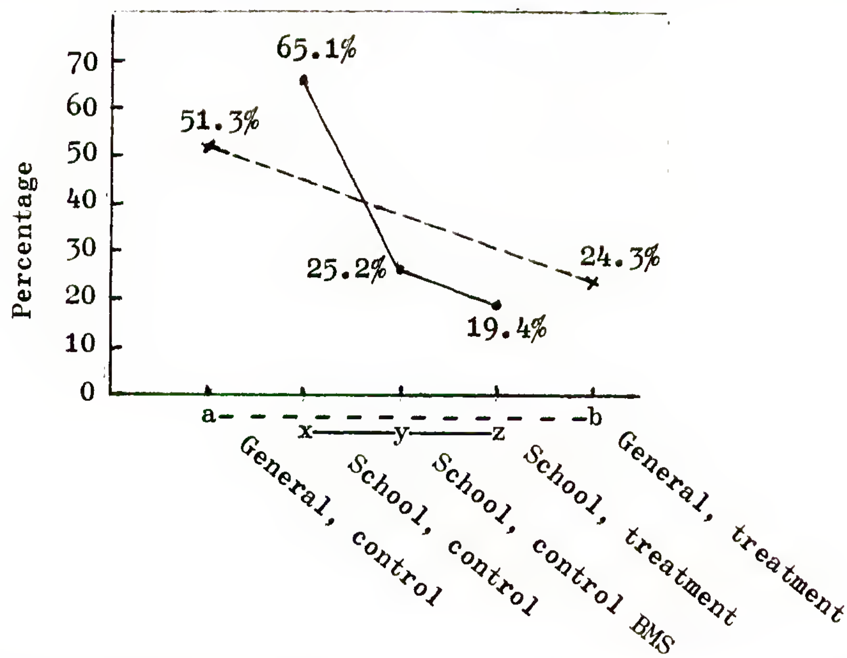
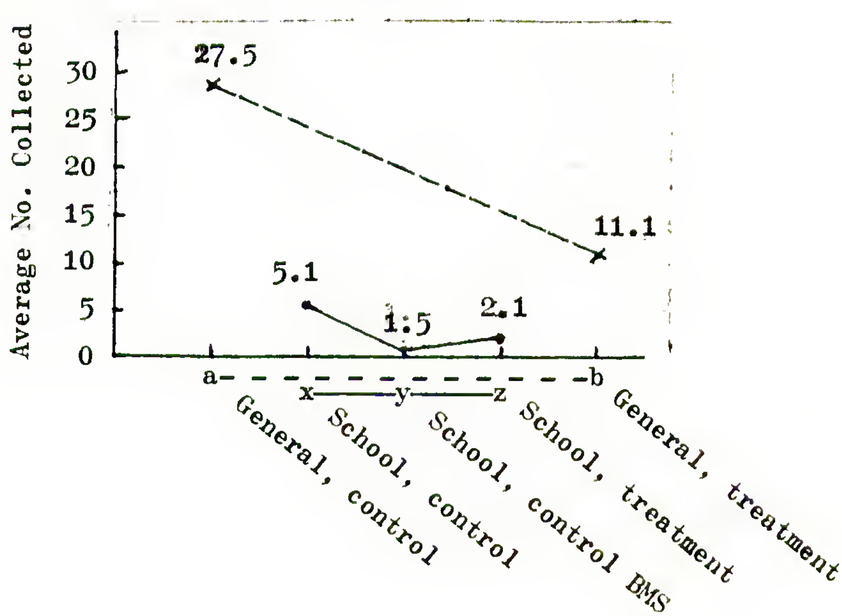


CHART S3b

Correlation of Conservation Education to the Average Number of Living Marine Animals Collected per Collector



CHAPTER IV

FINDINGS AND CONCLUSIONS

The analysis of what visitors, general public and school, do on a marine reef is not simple. Whenever one records the activities of animals, lower forms and humans, in any habitat, the result is a deluge of information and data, all reflecting the multi-choices of animalistic free will. My findings and conclusions on the variety of reef activities will be categorized in the following sequence:

A. The analysis of the physical sampling data of oxygen, salinity and temperature in and around the area of Duxbury Reef.

B. The analysis of number and species of marine animals collected in past years on Duxbury Reef.

C. The analysis of the research control data (no conservation education) and treatment data (conservation education) of visitors to the reef.

D. The analysis of the base count data on the changes in the distribution of marine animals.

E. The analysis of the effects of conservation education on the school populations visiting the reef.

F. Recommendations of the research report towards the future preservation of marine intertidal reefs.

A. ANALYSIS OF PHYSICAL SAMPLING DATA OF OXYGEN, SALINITY, AND TEMPERATURE

1. Data from Past Years

The search for past information on the physical sampling data of oxygen, salinity, and temperature on Duxbury Reef was not very productive. Outside of my own data collected in 1964 and 1969, I did not find any other reference on these parameters. Information for these same physical factors for past years was available for Fort Point near the Golden Gate Bridge. The comparison of data, Table 1, page 32, revealed that the difference in calculations from the data on hand was not very significant.

a. Dissolved oxygen: July, 1923 = 5.34 ml/liter (average)
July, 1969 = 2.6 ml/liter (average)

Investigator R. C. Miller and others stated that their dissolved oxygen Winkler measurements, taken in July of 1923, "were not accurate."[45] Generally marine scientists recognize that comparison of physical sampling data from one year to another carries with it many uncertainties as to the accuracy of laboratory techniques. Even data compiled by the same person in two consecutive years may contain errors due to improper calibration procedures.

The range of oxygen levels in the ocean is generally between 0 and 9 ml/liter, but the marine animals tolerate these extremes easily. F. A. Richards' analysis of the oxygen in the ocean is:

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[45]Miller, p. 260.

> It might seem that such extreme variations (0 to 9 ml per liter of dissolved oxygen) in an environmental factor would have an important effect on the distribution of species and population densities, but most marine organisms are physically better adapted to wide variations in oxygen tension than are many land organisms. Although there are wide variations in the respiratory requirements of marine organisms, the literature reveals no simple relationships between these requirements, the distribution of organisms, and population densities. Thus most organisms can withstand large variations in oxygen tension, and only at some low level are the variations reflected in the respiratory rate or survival (Von Ledebuhr, 1939).
>
> . . . It appears that in most parts of the ocean, the oxygen content is not a primary factor in limiting life and growth, except where sulfides develop under completely anaerobic conditions.[46]

b. Salinity: 1922-1969 difference in range = +4.4 o/oo

Temperature: 1923-1969 difference in range = -1.9° C

The laboratory techniques used in past measurements were not detailed in the literature. With this in mind and the passing of years in the measurements involved, the differences may be insignificant in light of the tolerances of intertidal animals.

Over the years, the salinity data on or near the exposed open coast of Duxbury Reef has risen about 4.4 parts per thousand (o/oo). Investigators Pearse and Gunter have revealed their conclusions concerning the salinity tolerances of marine organisms:

> . . . Marine species are not most abundant in coastal waters at low salinities [bays and estuaries] . They are

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[46] Francis A. Richards, Oxygen in the Oceans, 1957, Vol. 1, Memoir 67, Ecology, Treatise on Marine Ecology and Paleoecology, The Geological Society of America, National Academy of Sciences, Washington, D.C., 1963, pp. 211-213.

most abundant in coastal waters in full sea water (Gunter. 1945. 1950; Yonge, 1949). . . . It is admittedly difficult to differentiate all the factors that determine the presence of organisms within a salinity range. . . .

Field studies of distribution show that the number of species decline as salinity falls, and the weight of physiological evidence strongly indicates that salinity is definitely a limiting factor for marine organisms, especially when it varies downward [as in bays and estuaries] .[47]

Even though Duxbury Reef shows a salinity that has remained constant, or has risen very slightly, it is still difficult to use this information as the criteria for determining the distribution of organisms. Pearse and Gunter fully cautioned the interpretation of data:

. . . Mars (1950) . . . pointed out that experiments on salinity tolerance are difficult to carry out properly (and we might add also difficult to interpret) and that field observations yield dependable results if certain pitfalls (improper field procedures) are avoided.[48]

The temperature data on or near Duxbury Reef showed a slight 1.9° C decrease over the years, while there was very little change on the reef during the 1969 summer research period. Again, the interpretation of data is limited as to the effect of temperature on marine organisms.

Zoologist Gordon Gunter reported his conclusions on how vital temperature is to marine animals:

Temperature is the most important single factor governing the occurrence and behavior of life. . . .

There is a great mass of information available concerning temperature as an ecological factor, but its actual

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[47]A. S. Pearse and Gordon Gunter, Salinity, 1957, Vol. 1, Memoir 67, Ecology, Treatise on Marine Ecology and Paleoecology, The Geological Society of America, National Academy of Sciences, Washington, D.C., 1963, p. 149.

[48]Pearse and Gunter, p. 150

operation is sometimes difficult to evaluate. This is because many of the 'temperature' data are simply positions on a column of mercury, without consideration of gradients or duration. The rate of change, or temperature gradient, may be as important to the ecology of an organism as its total summation, its average, or its actual range within a given environment during a period of time.

The thermal death point for most terrestrial poikilotherms [warm blooded] is around 42° to 45° C: for marine animals it is lower, usually from 30° to 35° C, although for most shore or intertidal animals the lethal temperature is about the same as for terrestrial forms.[49]

2. Comparison of Research Period Data for Areas A,B,C of Duxbury Reef

The differences between the means in the three study areas A,B,C, as regards oxygen, salinity, and temperature, were very slight, as shown in Table 2, page 33:

Range of difference between the means of areas A,B,C =

.45 ml/liter for oxygen content

.20 o/oo for salinity

.6° C for temperature

The 95% confidence intervals for the range and the sample mean for each area is illustrated on Graph 2, page 34. The exact dates and readings for each area are contained in Appendix B. Since the differences between these areas are so slight, one may conclude that nearly the same physical conditions exist in all areas for oxygen, salinity and temperature factors.

Summary of the Physical Data Measurements

Intertidal animals are exposed to a wide variety of conditions throughout the year. In the summer of 1968, with very little protective fog cover on Duxbury Reef, I measured the temperature during one

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[49] Gordon Gunter, Temperature, 1957. Vol. 1, Memoir 67, Ecology, Treatise on Marine Ecology and Paleoecology, The Geological Society of America, National Academy of Sciences, Washington, D.C., 1963, pp. 159, 163.

low tide exposure on Area B as 28° C (82.4° F) on July 16th. On that same day, the salinity in the upper zone tidepools averaged 36 o oo. Marine intertidal animals have been able, through the eons of time, to compensate their existence for such extreme conditions during the rise and fall of tides through a variety of ecological adaptations (use of shells, kelp fronds, crevices, etc. to prevent dessication). In my twelve years of visits to Duxbury Reef, I have never observed the climatic physical conditions mentioned by Gunter-- temperature around 42°-45° C, when marine life would be treatened. Duxbury Reef is a reef exposed to the constant pounding of Pacific Ocean waves and such consistent physical conditions do not appear to have deterred marine life over the years.

The minor fluctuations in oxygen, salinity, and temperature on Duxbury Reef may truly exhibit the coastal environment as a stable marine habitat. Thus, the decrease in marine organisms on certain areas of Duxbury Reef, particularly area A, is not due to the recorded changes in the physical parameters of oxygen, salinity, and temperature.

3. Pesticides and other Pollutants

In today's environmental awareness of the general public and scientists at all levels, much attention has been given to the extent of pesticide pollution. Shellfish and other organisms have been examined for traces of chlorinated hydrocarbon pesticides; DDT, DDD, DDE, and dieldrin were routinely identified in California estuaries by John C. Modin of the California Marine Resources Operation laboratory of Menlo Park, California.

During a two-year period, Modin's investigations showed significantly higher pesticide pollutions in estuaries receiving runoff from large agricultural and urban areas. His studies also

revealed significant amounts of DDE in the larva of dungeness crabs, with the amount of "pesticides decreasing sharply in samples collected at increasing distances from the San Francisco Bay entrance."[50] Other studies revealed pesticides in king salmon, the California king crab, and various flatfish from the areas of Santa Barbara to Fort Bragg. Future investigations will determine the lethal pesticide levels in the marine environment.

Duxbury Reef is about twenty miles north of the Golden Gate Bridge and is probably not influenced by much agricultural drainage from the Northern California slopes. No investigation of the pesticides in Duxbury Reef organisms has yet been conducted, but it is my feeling that if such studies were made, some levels of pesticides would be found in the reef organisms. Determining the lethal dosage would again require much extended research.

In my research project, pesticides and other pollutants have no or little effect on the distribution of marine organisms. The Duxbury Reef areas (A,B,C) have the same shale substrate, are exposed to the same Westerlies and waves, and have relatively the same physical factors of oxygen, salinity and temperature. Area C, the control area, is abundant with marine intertidal life, while areas A and B are less dense in marine animals as shown in Table B1, page 59. Thus, if pesticides were the major cause of animal depletion in areas A and B, then the same depletion would also be seen in area C. Since area C does not show such ravaged conditions, I conclude that pesticides are not a contributing factor to the decreasing marine life on certain areas of Duxbury Reef.

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[50] John C. Modin, Chlorinated Hydrocarbon Pesticides in California Bays and Estuaries, State of California, Department of Fish and Game, Marine Resrouces Operation, Menlo Park, 1968, pp. 3-6.

B. <u>ANALYSIS OF THE NUMBERS AND SPECIES OF MARINE ANIMALS COLLECTED BY SCHOOL VISITORS IN PAST YEARS, 1961-1969, DUXBURY REEF</u>

Over the years, conservationists have observed hundreds of individuals, school students as well as the general public, return from the marine intertidal reefs of California with buckets filled with marine organisms. Conservationists have looked at these scenes and have done relatively little to curb this unrestrained collecting. Only in the last three years have there been some attempts to set aside marine areas as animal refuges; some of these areas will be discussed later under the "recommendations" section of this report. The apathy of conservationists has resulted in a continual depletion of marine reefs. With this hindsight, I will begin to lay out the results of what people have done to a particular marine reef in hopes that the information will awaken the public and the educational institutions to reform their collecting habits.

With the knowledge that no data exists on what had been removed from intertidal reefs, the attempt to gather past information was met with some difficulty. Polling the general public was, in my opinion, not possible. Polling the school teachers was the most pactical step, and I decided that attempting a survey with Marin County teachers only, from elementary through college, was the most feasible method. The questionnaire form, Appendix C, was to be completed by teachers of all grade levels who have conducted field trips to Duxbury Reef in the past and then returned to me. With conservation being a popular concept, twelve teachers informed me that they would not reveal what they had collected because this was "personal" information. Nevertheless, the collecting data submitted by thirty-two teachers was combined with other sources of past data, page 35; my interpretation of this data follows.

1. <u>Teachers' Responses to the Past-Collecting Questionnaire (Appendix C)</u>

   a. Elementary teachers were the most numerous in responding to the questionnaire.

      21 elementary teachers
       8 secondary teachers
       3 college teachers
      32 total

   b. The reasons why teachers visit Duxbury Reef are listed below (Appendix C, question 7); some teachers checked more than one reason.

      9 visited the reef to make collections for their laboratories and aquarias

      8 stated that collections by students were used for individual projects

      2 stated that collections were made for museum display

      6 stated that collections were made to stimulate pupil interest

      23 stated that they used the reef for other reasons. Of these teachers, 21 visited the reef to observe some form of ecology patterns. Only 2 used the reef for research projects; both were college teachers. Twelve replied that they made no collection whatsoever.

   The percentage of teachers who did collect was 63%. The apparent pressure of putting down numbers of organisms collected did not meet with a large response. The actual observation of teachers and students on the reef during the research period of June 1969 revealed a much higher percentage. In that five-week research period, 18 of the 22 Marin County school classes that visited Duxbury Reef collected marine organisms, making a collecting percentage of 82%. Thus, the collection reporting by the sample of 32 teachers gives conservative numbers of animals collected.

c. The area of the reef most visited by teachers in past years was area A, with area B a very close second. These teachers and their classes generally visited more than one area of Duxbury Reef. The following responses indicated their preference for the easy access areas of A and B.

Area A - visited by 17 teachers and their classes
Area B - visited by 16 teachers and their classes
Area C - visited by 8 teachers and their classes

2. Combining All Past Data on School Collectors, 1961-1969

The information provided in the overall pictures of past collectors, pages 35-38, illustrates the greater preponderance of visitors (Graph 2a, page 36) and number of animals collected (Table 3, page 37) for the half year (January-July) of 1969. These larger numbers are due to the fact that the May 30-July 3 daily research data was added to the number of January through May, making a more accurate sample count for the 91 days of observation. No doubt if such similarly precise daily observations were recorded for other past years, the totals would be much higher. However, in my opinion, the total 1961-1969 information provided in the composite data is a good representative sample of what has occurred on the reef from year to year.

3. Summary of Collecting Data, 1961-1969

a. The number of school visitors to the reef has increased each year. In 1961 the total number of school visitors was 165. The numbers climbed slowly and in 1966, the sample total was 2,328 (see below). Similarly, the average number of visitors

(Excerpts from Graphs 2a and 2b, page 36, NUMBER OF VISITORS)

Year =	1961	1962	1963	1964	1965	1966	1967	1968	1969
Total Visitors =	165	193	348	594	974	2328	2379	4785	6104
Days =	15	16	27	44	50	49	62	75	91
Average/Day =	11	12	12	13	19	47	38	63	67

per day was fairly consistent, between 11 in 1961 and 19 in 1965. However, in 1966, the average number of visitors per day rose to 47.

This sudden rise in the number of visitors per day to the reef may be attributed to:

(1) The acceleration of marine ecology units into the elementary and grade school textbooks. An article revealed:

> Although each of the units of the text offers much that is new, perhaps of signal interest to the teacher of earth science will be the comprehensive and authoritative treatment of oceanography which is included to a degree hitherto unknown in earth science texts.[51]

(2) The first television showing of the famed French oceanographer, titled, "The World of Jacques Cousteau."

(3) The big upsurge in "The National Oceanographic Program for Fiscal Year 1966," especially the activities of the U.S. Congress that passed S944 introduced by Senator Warren Magnusson, which declared a national policy in the oceans.[52]

Whatever caused the acceleration of school visitors to the reef in 1966 may not be easily determined, but since 1966 the totals visiting the reef now number into the thousands per year.

b. The totals and species of marine organisms collected by school groups are contained in Table 3, page 37. Of the most collected species in the top ten, five are mollusks. The table shows

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[51] C. Wroe Wolfe, and others, Earth and Space Science, (Boston: D. C. Heath and Company, 1966) p. v.

[52] Robert B. Abel, "The National Oceanographic Program," Oceanology, (June 15, 1966), p. 33.

that with more visitors over the past years, 1961-1969, more animals were also being collected from the reef, 557 in 1961 and 1023 in 1968. One of the most interesting pieces of data uncovered in this report is shown in the excerpt below:

(Excerpts from Graphs 2a and 3, pages 36, 37, AVERAGE NUMBER OF MARINE ANIMALS COLLECTED)

Year	Avg. No. collected per collector	Total No. of Visitors per low tide day
1961	4.1	165
1962	3.9	193
1963	5.2	348
1964	4.0	594
1965	3.3	974
1966	3.2	2328
1967	2.6	2379
1968	2.5	4785

Note that while the number of school visitors rose, and likewise, the total numbers of animals collected rose, the <u>average number of animals collected per collector declined</u>! This drop in organisms collected per collector is clearly viewed if the half year of 1969 is omitted. (Again, the 1969 data includes the day-by-day tallies of the May 30-July 3 period which is part of the specific study of this research report.)

The cause for the decline in the average number of animals collected per collector may be attributed to the following:

(1) Since approximately 80% of the teachers who responded to the survey stated that they visited areas A and B, 1961-1969, and since my observations of May 30-July 3, 1969, recorded that about 82% of the Marin teachers and their groups collect marine organisms, I conclude then that the collecting drive is still strong, but in the later years, 1965-1968, there were simply less desirable organisms available for collecting! Four of the teachers in the

survey stated that their collecting tapered off because of fewer choice animals in areas A and B!

In Table 3, page 37, some of the major, more sessile and popular organisms were collected less each year. For example, Pisaster spp. (the starfish) was definitely collected less each year, 190 in 1964 and 60 in 1968.

(Excerpt from Table 3, page 37, LIVING MARINE ANIMALS COLLECTED)

Year -	1961	1962	1963	1964	1965	1966	1967	1968	1969
Pisaster spp.	80	50	63	190	169	54	53	60	55
Mytilus californianus	72	60	126	171	168	156	138	158	127

The seastars (I will use this word instead of the more popular "starfish") principally feed on the California mussel. The excerpt above shows a high average take of about 130 mussels per year for a small sample of 20 collecting teachers and their classes. The actual number taken per year off the reef would include those taken by the general public for fish bait and for consumption at home, as well as those taken by all other school visiting classes. Thus, we have the following situation:

(a) There are less mussels for seastars to feed on, so the seastars move to deeper waters for food.

(b) There are less seastars because of collectors as well as reason mentioned in (a).

(c) Therefore, there is a reduced number of seastars available for collectors to pick up in each succeeding year.

During the July research period of conservation education, I planted seastars in area A tidepools on two separate occasions. Even with conservation education reminding individuals not to collect, these seastars were quickly put into buckets by school visitors without hesitation.

(2) The second hypothesis for a lower number of animals collected per collector is the one I'm hoping is the real reason, and that is, teachers and students are becoming more conservation oriented. In the past three years, conservation has been a theme throughout the news media. The words "environment" and "ecology", once poorly understood, are now common terms. Certainly in the questionnaire to the teachers asking for past collecting data, 23 teachers used the words "ecology" or "conservation" for their reasons in visiting the reef.

(3) The final hypothesis for the decline in the average number collected is that perhaps the sample survey of the school teachers and collectors throughout the years 1961-1969 was not representative. The lack of data on reef visitors and other unknowns concerning what they do collect has been the shortcoming of any real dixcussion on what has happened to marine intertidal reefs in past years.

Furthermore, the past data indicated that secondary and college visitors collect twice as many organisms as elementary visitors,- 6,182 compared to 2,703 animals- (Graph 4, page 38). Does this indicate that secondary and college students and teachers do more damage to the reef than elementary visitors? Or is this sample information

another misrepresentation of what really occurred in the years 1961-1969?

In summary, the information from the past years lend some help to the understanding of what animals, both in totals and in species, have been collected. The data provides some insight into the trends of increasing number of visitors, increasing total numbers of animals collected, but fewer organisms collected per collector. The major help of this past data to me is to stimulate into action the setting aside of a period of time in which experimentation and observation will measure as many unknowns as possible. For the first time on any United States sea coast, the analysis of general public and school visitors will be measured in a fixed experimental period--this information follows.

C. ANALYSIS OF THE COMPARISONS BETWEEN RESEARCH CONTROL AND TREATMENT DATA OF VISITORS TO THE REEF

A period of ten weeks was set aside as the experiment model to determine what actually happens when people visit Duxbury Reef. The rationale for this time period was described on pages 21-23. In review:

Dates	Duration	Title of Period	Experiment
May 30 - July 3	5 weeks	Control	Record all activities (with no conservation education)
July 4-August 7	5 weeks	Treatment	Record all activities (with conservation education)

The comparison of the activities of both periods may be seen on the tables, graphs, and charts of pages 44 - 57.

1. The Numbers of Visitors to the Reef

Summary of Tables C1 and T1, page 44:

	School	General Public	Totals	Average Per Day
Control Sample	1,380	1,158	2,538	72
Treatment Sample	959	781	1,740	49

These figures indicate that more visitors went to the reef during the control period. The reasons for the greater number during this period may be attributed to the following:

a. There were 23 favorable minus tides in the control period as compared to 16 for the treatment period. Minus tides expose more reef and hence are a major prerequisite for a successful trip. The minus tides were also lower during the control period, reaching a -2.0 twice during the first week; 1,024 persons visited the reef during this week, slightly less than 50% of the total number of visitors for the entire five-week period!

In 1968, the reef attendance was taken during two weeks of the summer, and the data supports the 1969 results:

Week	Lowest Tide	Tide Range	Time Range of Tides	Number of Visitors
June 9-15	-2.1	-1.8 to -1.5	5:45 AM to 10:30 AM	1,113
July 7-13	-1.9	-1.4 to -1.0	4:42 AM to 9:00 AM	720

b. Summer school classes usually begin the middle of June and and run through the month of July. More children are available to visit the reefs as a class during the first part of the summer than during the latter part.

Although there may be other contributing factors, I feel that the favorable tides and the availability of school groups constitute the major reasons for the greater number of visitors during the control period.

2. The Home Areas of the Reef Visitors

Of the total visitors that come to Duxbury Reef during both control and treatment periods, approximately 64% come from Marin County. If the visitors from the San Francisco Bay area

are added to those from Marin County, the percentage for the combined areas would be 83% of the total number of visitors.

Summary from data in Tables C2, T2. Charts C3, T3, and Tables C4. T4, pages 45-47:

Home Areas of Visitors	Control Sample (2,538 visitors) Number	Percentage	Treatment Sample (1,740 visitors) Number	Percentage
Marin County	1,350	53.2%	1,404	80.7%
San Francisco Bay Area + Marin	1,952	76.9%	1,592	91.5%
Marin County school visitors	875	34.5%	880	50.6%
Marin County general visitors	475	18.7%	524	30.1%

In some instances, particularly during the control period, it was not possible to interview each visitor to ask his home area when there were so many people on the reef at one time. Those not interviewed are grouped in the "unknown" home area classification.

Tables C2 and T2, page 45, describe the location of visitors from regions outside the San Francisco Bay area, with nearly every township represented in Northern California. Of the ten states represented, Florida was the most distant, while Australia ranked as the lone foreign country.

The great majority of reef visitors, 64% for the ten weeks, came from Marin County, while 28% came from non-Marin areas (18% from San Francisco Bay area). A total of 4,278 persons visited the reef in ten weeks, an average of 61 persons a day (Tables C4 and T4, page 47).

3. The Duxbury Reef Areas Visited by People

From information contained in Tables C5 and T5, and Tables C6 and T6, pages 48 and 49:

a. Percentage of all visitors for each reef area

		Area A	Area B	Area C	More than one Area
Control sample	(2,538):	2,179	638	143	395
% of control visitors:		(86%)	(25%)	(6%)	(16%)
Treatment sample	(1,740):	1,559	527	126	437
% of treatment visitors:		(90%)	(30%)	(7%)	(25%)
	4,278	3,738	1,165	269	832
	100%	87%	27%	6%	19%

With the easy access to area A, we find that almost 9 out of every 10 visitors (87%) went to area A, almost 3 out of every 10 (27%) went to area B, but only 6 out of every 100 visited area C! In terms of ratios, the number of visitors for areas A:B:C would be 29:9:2 or about 15:5:1, or about 15 times as many visitors for area A as there were for area C.

b. School groups visiting the reef

			Area A	Area B	Area C	More than one area
Control	1,380	(100%):	1,324(96%)	350(25%)	72(5%)	339(25%)
Treatment	959	(100%):	909(95%)	368(38%)	77(8%)	362(38%)
	2,339	(100%):	2,233(95%)	718(31%)	149(6%)	701(30%)

School groups show pronounced preference for visiting area A (95%), while the percentages of school visitors in areas B and C are similar to percentages for all visitors. Almost one-third of all school visitors visit more than one area. The ratio of visitors in areas A:B:C is about 16:5:1.

c. General public visiting the reef

			Area A	Area B	Area C	More than one area
Control	1,158	(100%):	855(74%)	288(25%)	71(6%)	56(5%)
Treatment	781	(100%):	650(83%)	159(20%)	49(6%)	75(10%)
	1,939	(100%):	1,505(78%)	447(23%)	120(6%)	131(7%)

The percentages of general visitors for areas A and B are lower than those of school visitors and reflect the fact that only 7 out of 100 general visitors visit more than one area compared to 30 out of 100 school visitors. The ratio of general visitors in areas A:B:C is 13:4:1.

4. The Activities of Visitors on the Reef

Observing the visitors to the reef and then classifying their activities was a relatively easy task. For example:

If visitor carried a bucket or plastic bag = collector

If visitor carried a bucket and pick = clam digger (collector)

If visitor carried a fishing pole = fisherman

If visitor did not carry any collecting gear = non-collector

Many individuals did not carry collecting gear, yet used pockets and purses for collecting shells and rocks; these visitors were classified as collectors.

The following analysis is based on data contained in Tables C7 and T7, C8 and T8, on pages 50 and 51.

a. <u>All Visitors</u>

Employing the general classifications of Fishermen, Collectors (all types), and Non-Collectors for all visitors, we arrive at these totals:

	Fishermen	Collectors	Non-Collectors
Control sample:	193 (7.6%)	1,493 (58.8%)	852 (33.6%)
Treatment sample:	193 (11.1%)	376 (21.6%)	1,171 (67.3%)
Effect of conservation education:		-37.2%	+33.7%

The percentage of visitors who collect decreased from 58.8% for control sample to 21.6% for treatment sample. In accord, the percentage of visitors who do not collect increased from 33.6% for control sample to 67.3% for treatment sample. Conservation education on the reef does effect a change in the collecting behavior of visitors, reducing the percentage who collect by about 35%

b. <u>Comparison of School Visitors</u>

	Fishermen	Collectors	Non-Collectors
Control sample:	-	899 (65.1%)	481 (34.9%)
Treatment sample:	-	186 (19.4%)	773 (80.6%)
Effect of conservation education:		-45.7%	+45.7%

With conservation education, a great improvement in the collecting behavior of school collectors is noted, a reduction of 45% in the percentage of school visitors who collect.

c. Comparison of General Visitors

	Fishermen	Collectors	Non-Collectors
Control sample:	193 (16.7%)	594 (51.3%)	371 (32.0%)
Treatment sample:	193 (24.7%)	190 (24.3%)	398 (51.0%)
Effect of conservation education:		-27.0%	+18.0%

Conservation education reduced the percentage of visitors who collect by 27% for general visitors.

d. Ratio of Collectors to Non-Collectors

	Control sample	Treatment sample
All Visitors:	2:1	1:3
School Visitors:	2:1	1:4
General Visitors:	5:3	1:2

For both school and general groups, the treatment ratios of collectors to non-collectors show a definite improvement over the control ratio.

e. Other Comparisons between Control and Treatment Samples

(1) Types of Activities (Tables C7 and T7, page 50)

(a) Fishermen-- There were 20 fishermen in the control sample and 26 in the treatment sample who pried off living animals from the reef, mussels and chitons, to use as fish bait. These individuals were classified as "collectors", not "fishermen".

(b) Rock Clam Fishermen-- Visitors who came to the reef with picks, chisels, hammers, and buckets to dig the rock clam, *Platyodon cancellatus*, out of the shale reef were all general public visitors who did their digging during the low tides of the control period. Eight individuals came to dig for these same clams during the treatment period and were convinced by conservation education conducted at the reef to lay down their picks; they were not too happy with this

challenge to their sporting rights.

(c) Collectors of living marine animals-- These are collectors for whom the exact number and species of animals collected are recorded research data. Collectors for whom no count and species were available are the "unknown" collectors described below.

(d) Other Collectors-- This classification refers to visitors who collect shells, algae, rocks (agates), driftwood, glass, and boards, sometimes from an area as far as the Radio Communications Corporation (RCA) Station, one mile north of area A. In my opinion, these individuals remove a significant amount of materials which in time will not be available under the current trend.

(e) Unknown Collectors-- This group consists of collectors who were not detected as to the number and species of items collected. Many of these individuals were seen picking up items and leaving the reef before the research investigators could tally their specific catch on the recording sheet (Appendix H). Such occurrences were common on days when hundreds of visitors descended on to the reef.

(f) Non-Collectors-- These individuals did not remove items from the reef. However, all visitors who walk on the reef cause some, often much, damage. Under the control period, a class of 75 elementary students arrived at area A without collecting apparatus, but the students proceeded to uproot hundreds of living organisms, causing great displacement; twelve of these

students were observed having a "rock" fight by tossing Tegula. the black turban snail. at each other. The teacher of the group claimed that she teaches conservation of marine animals in her classroom.

During the treatment period, 85 non-collectors, students of an elementary school, were given the conservation education lecture and literature. Previous to their arrival I had planted _Pisaster ochraceous_ (purple seastar) and _Cancer antennarius_ (red rock crab) in easily accessible tidepools in area A. As soon as the students arrived on the reef, they picked up the seastar and crab approximately fifty times and replaced them in a variety of pools and positions. The female rock crab was dead after the eighth time of being picked up and discarded, and the seastar disappeared along the way.

I repeated the above "salted" treatment the next day on another group of 50 elementary students, but now with an emphatic "hands off" policy on any living creatures. As soon as the students observed the seastar and crab, the "pick it up, run to show it to friends, and toss it back into a tidepool" routine was repeated over and over again.

One of my major future concerns is to determine how to tone down the insatiable urge of students to pick up animals when coming to the reef to observe and "conserve" marine animals. Perhaps the fences in

zoos are really for keeping the humans out!

(2) Overall Effect of Conservation Education

(a) On Collectors of Living Marine Animals

	Collectors Rock Clams		Collectors Organisms		Collectors Unknown		
All Visitors							
Control:	1.5%	+	26.4%	+	17.8%	=	45.7%
Treatment:	-		11.8%	+	4.2%	=	16.0%
					Effect:		-29.7%
School Visitors							
Control:	-		26.8%	+	24.0%	=	50.8%
Treatment:	-		16.0%	+	3.4%	=	19.4%
					Effect:		-31.4%
General Visitors							
Control:	3.2%	+	26.0%	+	10.4%	=	39.6%
Treatment:	-		6.7%	+	5.1%	=	11.8%
					Effect:		-27.8%

The percentage of visitors who collect living marine animals, number known and unknown, decreased from 45.7% in control to 16.0% in treatment, a reduction of 28.2%. The improvement in the collecting behavior of school visitors was slightly higher than that for general visitors, in terms of percentage.

(b) On Collectors of Non-living Materials

	Other Collectors			
	School		General	
Control:	198	(14.3%)	135	(11.7%)
Treatment:	0	-	98	(12.5%)
Effect:		-14.3%		+0.8%

While the percentage of school visitors who collect other materials was reduced by 14.3%, the percentage of general visitors who collect other materials went up a scant 0.8%, or underwent negligible change. Apparently, these general visitors felt that

the suggestion of "no collecting" pertained only to reef animals, and it is true that our conservation education was aimed primarily at animal collectors.

5. The Number of Living Marine Animals Collected

Tables C9, T9, C10, and T10, of pages 52 and 53, illustrate the number of the major species collected and the totals of all animals collected during the control and treatment periods. From these tables and charts, the following summary reveals:

a. The total numbers of living animals collected by all collectors

	Area A	Area B	Area C	Totals
Control:	8206 (75%)	2425 (22%)	341 (3%)	10,972 (100%)
Treatment:	218 (24%)	495 (56%)	181 (20%)	894 (100%)
Totals:	8424 (71%)	2920 (25%)	522 (4%)	11,866 (100%)

For the ten weeks, 71% of the known count of living marine animals were taken from area A, 25% from area B, and 4% from area C. Since 87% of all visitors went to area A, one can easily see why so many animals are stripped from this area.

In the control sample, 75% of the animals collected were taken from area A, as compared to only 22% from area B and a mere 3% from area C. A decided contrast occurred in the treatment sample when 56% of the animals collected were taken from area B, and the percentages from area A and C were fairly equal, a much greater percentage for area C than in the control period. During the treatment period, two school groups, despite conservation education, went into areas B and C to collect marine organisms to fulfill each student's project of making a representative phyla collection from intertidal reefs. Each teacher of these groups has a long history of coming to Duxbury Reef to collect organisms and was quite familiar with the

greater abundance of marine life in area C. This situation no doubt influenced the higher percentage of animals collected in areas B and C.

b. Collecting Preferences

Charts C10 and T10, page 53, show that school visitors collected more crabs, seastars, chitons and sea urchins than the general public. However, the general public collected more of the edible animals, as in the molluscans, e.g., snails, rock clams, mussels (for bait), and limpets. In Table C11, page 54, this unbalanced collecting stands out (for individuals who were observed to collect 50 or more Tegula or Platyodon).

Number of Visitors		Animals Collected
6 school	collected	300 Tegula
12 general public	collected	4,250 Tegula
37 general public	collected	3,410 Platyodon

Just a small group of general public visitors collected thousands of black turban snails and rock clams for consumption purposes during the control period. During the treatment period, there were no clam diggers and two general visitors collected 200 snails.

c. Summary Comparisons

(Excerpts from Tables C11 and T11, page 54, OBSERVED COLLECTORS OF MARINE ANIMALS)

(1) Number of Collectors

	School	General	
Control	370	338	= 708
Treatment	153	52	= 205
	523	390	913

(2) Number of Animals Collected

	School	General
Control	1,676	9,296
Treatment	319	575

(3) Average Number of Animals Collected Per Collector

	School	General
Control	4.5	27.5
Treatment	2.1	11.1

	(4) Percentage of Collectors		(5) Percentage of Animals Collected	
	School	General	School	General
Control	52.3%	47.7%	15.3%	84.7%
Treatment	74.6%	25.4%	35.7%	64.3%

d. General Statements about the Above Data (item c.)

(1) The general public collected more animals than school visitors, even though there were 523 school collectors in comparison to 390 general public collectors. Again, one must consider that 12 and 37 general visitors collected 4,250 snails and 3,410 rock clams, respectively. However, the number of school collectors, item c(4) above, constitutes over 50% of all collectors for both control and treatment periods.

(2) With the anomalies of large numbers of snails and rock clams collected, the average number of animals collected per collector, item c(3) of page 91, is much greater for the general public than for school visitors. My studies show that school visitors will collect more of certain species, and similarly, the general public will collect more of the edible mollusk species.

(3) The treatment period of conservation education did effectively reduce the average number of animals collected per collectors for both school and general visitors, item c(3).

(4) As regards the ratio of collectors during the control period, school collectors to general collectors was nearly 1:1, item c(4), for the 708 collectors. However, in the treatment period, out of a total of 205 collectors, there were three school collectors for each single general

collector. Again, this ratio is the result, partially, of two school groups which "had to" make collections to complete student projects.

6. Comparison of School Visitors -- Elementary, Secondary, and College

The analysis in this section is based on data contained in Tables C12 and T12, Charts C13 and T13, pages 55 and 56.

a. Three-fourths of all school visitors to the reef were elementary students and teachers.

School Groups on the Reef

	Elementary	Secondary	College
Control:	1,083 (78%)	175 (13%)	122 (9%)
Treatment:	684 (71%)	140 (32%)	135 (14%)

b. For the control period, elementary visitors constitute the greater majority (67%) of school visitors who collect living marine animals. As one might expect, the greatest number of organisms collected was collected by elementary school collectors. In the treatment period, all three school groups represented almost equal proportions of total number of school visitors who collect, with the college group being the smallest proportion.

Collectors of Living Marine Animals

* = number of animals collected

	Elementary	*	Secondary	*	College	*	
Control:	249 (67%)	1,266	47 (13%)	278	75 (20%)	132	= 100%
Treatment:	60 (39%)	101	58 (38%)	151	35 (23%)	67	= 100%

c. For the percentages of each school group of visitors who collect living marine animals, the following tables shows:

Collectors of Living Marine Animals per Group

	Elementary	Secondary	College
Control:	249/1083 = 21%	46/175 = 26%	75/122 = 61%
Treatment:	60/684 = 8%	58/140 = 41%	35/135 = 26%
Effect:	-13%	+15%	-35%

The treatment sample shows a reduced percentage of known collecting of living marine animals for both elementary and college groups, but an increased percentage for the high school group. That increase was due to two classes which "had to" make collections to fulfill student projects in their marine summer classes. The reduced percentage for elementary visitors was not as high as that for college visitors for two reasons: (1) the elementary percentage of 21% in the control was low to begin with because one-fifth of all control elementary visitors, 214 out of 1083, was guided and instructed on the reef by Bolinas Marine Station staff, (2) there were 315 elementary visitors in the control period who were observed collecting marine animals, but whose number of organisms collected could not be counted; these 315 are in the "unknown quantity collectors" classification.

d. For all types of collecting, the percentage of school visitors who collect is significantly greater than the percentage of general visitors who collect for the control period. For the treatment period, however, the percentage of school visitors who collect is significantly less than the percentage of general visitors who collect. Test statistics were used, Appendices D and E, to test significance of difference and intervals of difference between the two population groups were computed:

	Collectors	
	School	General
Control:	899/1380= 65.1%	594/1158= 51.3%
Treatment:	186/959 = 19.4%	190/181 = 24.3%

Population Interval Estimate of Difference

Control: Proportion of school visitors who collect is greater than proportion of general visitors who collect by 10.0% to 17.6% inclusive.

Treatment: Percentage of school visitors who collect is less than percentage of general visitors who collect by 1.0% to 8.8% inclusive.

e. The percentages of each school group of visitors who collect are:

	Elementary	Secondary	College
Control:	752/1083= 69.4%	47/175= 26.3%	101/122= 82.8%
Treatment:	90/684 = 13.2%	58/140= 41.4%	38/135= 28.1%

By test statistics, the percentages for the three school groups for control and for treatment samples are significantly different from each other. The population interval estimates of difference are:

Control: The percentage of college visitors who collect is 6.2% to 20.6% inclusive greater than the percentage of elementary visitors who collect; the percentage of elementary visitors who collect, in turn, is 36.1% to 50.1% inclusive greater than the percentage of secondary visitors who collect. The percentage of college visitors who collect is 47.2% to 65.8% inclusive greater than the percentage of secondary visitors who collect.

Treatment: The percentage of secondary visitors who collect is 2.2% to 24.4% inclusive greater than the percentage of college visitors who collect; the percentage of college visitors who collect, in turn, is 6.9% to 22.9% inclusive greater than the percentage of elementary visitors who collect. The percentage of secondary visitors who collect is 19.6% to 36.7% inclusive greater than the percentage of elementary visitors who collect.

f. The overall average number of animals collected per school collector was significantly reduced during the treatment period of conservation education.

	Average Number of Animals Collected/Collector			
	Elementary	Secondary	College	Overall Avg.
Control	5.1	6.0	1.8	4.5
Treatment	1.7	2.6	1.9	2.1

g. There was a significant reduction in the total number of marine species collected during the treatment period.

Control: 10,972 animals Treatment: 894 animals

D. ANALYSIS OF BASE COUNT DATA ON THE DISTRIBUTION OF MARINE ANIMALS

In each of the areas A,B, and C, five transects were laid out, each ten meters long, and animals were counted in each square meter measured along one side of each transect. The purpose of these base count transects, fifteenin total, was to determine if there were any significant changes in the distribution of marine animals during the ten-week research period. Three base counts were taken, one at the beginning of the control period, one at the end of the control period (also the beginning of the treatment period), and one at the end of the treatment period. Table B1, page 59, indicates the dates of transect square meter measurements and the summary information on the animal distribution for each base count in each area.

The central hypothesis of these base count measurements is that if collecting is constant in areas A and B of the reef, these base counts should show greater fluctuations than the counts in area C; and if conservation education is introduced and is effective, the base counts in areas of collecting should show stability in animal distribution.

Six major animals were chose, Table B1, page 59, because of their large, countable size. Other animals were also tabulated in the base counts, but were not entered in the statistical analysis.

1. The Overall Results of Base Counts 1, 2, and 3 -- Table B1, page 59

Area	Base Counts	Total Animals	Change from Count 1 to 2 (for 50 sq. meter plots)	Known total number of animals collected during control period
A	1	1,275		
	2	883	-392	8,206
	3	1,361		
B	1	2,567		
	2	1,532	-1,035	2,425
	3	2,485		

Area	Base Counts	Total Animals	Change from Count 1 to 2	Known total number of animals collected during control period
C	1	22,364		
	2	22,697	+333	341
	3	22,284		

General Results

a. The base count 2 for areas A and B show reduction in overall numbers, but in area C show an increase. Base count 2 in area B decreased the most, by 1034 animals for 50 square meters, and area A, the least, by 392 animals for 50 square meters. Yet, the number of organisms collected in area A was the highest, 8206! The increase of 333 for 50 square meters in base count 2 for area C may be due to the mobility of snails.

b. The analysis of differences between base counts 1 and 2 will be made primarily for area A which had the most significant amount of collecting.

The Reduction in the Number of Three Species in Base Count 2 for Area A

Animals	Base Counts 1	2	change 1 to 2	Total collected (control)	3	change 2 to 3
Mytilus californianus (mussel)	126	82	-34	220	82	0
Tegula funebralis (turban snail)	1,117	782	-339	4990	1,271	+489
Acanthina spirata (rock snail	26	16	-10	no counts	2	-14

(1) The number of mussels collected was 220 in the control period, and the difference is reflected in base count 2 with a reduction of 34 mussels for 50 square meters. In the treatment period, no collecting of mussels was observed. Thus, base count 3 showed stability at 82

mussels. The mussle is a sessile-attached organism.

(2) There were 4,990 Tegula snails collected during the control period, and base count 2 reflected a loss of 339 snails for 50 square meters. During the treatment period, 84 Tegulas were collected, yet base count 3 increased by 489 for 50 square meters. The mobility of this snail probably accounted for most of the reduction of organisms in area B from base count 1 to 2.

(3) *Acanthina spirata* is also a very mobile snail and with Tegula shows much decrease and recovery in base counts 2 and 3 in areas B and C (Graph B1, page 60).

2. Analysis of the Cyclical Base Counts

a. Invertebrate growth is slow

The reproductive abilities of the six different organisms take a longer time to develop than the ten-week research period. Dr. Libbie H. Hyman, world authority on invertebrates, has placed the growth of mollusks at a slow rate, few maturing at less than one year old.[53] Seastars, or starfish, also have a growth rate, estimated by Dr. Hyman, whereby maturity and spawning occur at about one year of age.[54] In my own research on the growth and age of *Anthopleura xanthogrammica*, the green sea anemone, I have found that in ten years of constant feeding and observation of one single specimen, it had gained two inches in diameter. One sea anemone has been kept as a pet in

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[53] L. H. Hyman, *The Invertebrata: Mollusca I* (New York, McGraw-Hill, 1967) p. 111.

[54] L. H. Hyman, *The Invertebrata: Echinodermata* (New York, McGraw-Hill, 1955) p. 412.

England and it is well over sixty years old![55] Therefore, whether it be a sessile or mobile invertebrate, none of the species studied can reproduce into a countable, mature, macro-sized organism within the ten-week research period.

One of the keys to stability in an intertidal reef is the restoration of the mussel beds of Mytilus californianus. If the current mussel beds in areas A and B were permitted to reproduce, within ten years, there would be significant rehabilitated patches of these mollusks. In 1958, I scraped off six patches of mussels:

Date	Shape of Scraped Area	No. of Patches	Year of Complete Restoration	No. of years Complete Succession
April 4, 1958	One foot wide, ten feet long	3		
		Strip a=	May, 1968	10
		Strip b=	Dec., 1967	9
		Strip c=	Aug., 1969	11
	Square meter	3		
		Sq. meter a=	Apr., 1965	7
		Sq. meter b=	June, 1964	6
		Sq. meter c=	Dec., 1967	9

The square meter areas were restored in a shorter time than the ten-foot strips. The aim of this report is not to discuss the biology of mussel succession; Hewatt's work may be reviewed for this purpose.[56] Great numbers of marine organisms live within the protective beds of the mussels. When Hewatt cleared his square meter patch in 1931, he uncovered about twenty species of organisms totaling 5,210 animals. One of my former students, Gary Williams, studied a mussel patch in area C of Duxbury Reef and isolated about thirty species of animals

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[55] Chan, p. 20.

[56] Joel W. Hedgpeth, Between Pacific Tides, (Stanford University Press, 1968, revised) p. 398.

and sixteen species of marine algae living within the mussel bed.[57] Thus, marine biologists have come to recognize that mussel beds form a rich habitat for large numbers of marine organisms.

b. Much mobility in sea snails

The cause of decreases in animal density in base count 2 during the control period may well be the collecting behavior of the reef visitors; this would be especially true with sessile organisms such as mussels and sea anemones. However, with the snails and seastars, collecting may be a factor in the reduction of numbers, but I have concluded that their mobility in and around the reef is one of the major causes for the cyclical distribution measurements. Dr. Hyman states:

> Intertidal snails are governed by the tides. Such snails are inert and motionless while exposed at low tide and resume activity when splashed or submerged by the returning tide.[58]

Mr. James Dinsmore of the Pacific Marine Station at Dillon Beach, California, found that Tegula funebralis, the black turban snail, will migrate large distances in a twenty-four-hour period.[59]

In my own investigation of Tegula along the area A base count transects, I used a four-day tracking of one large Tegula, age six years, with six growth lines. The following Figure 1, page 101, shows its movements with the corresponding

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[57] Chan, p. 52.

[58] Hyman, The Invertebrata: Mollusca I, p. 344.

[59] James Dinsmore, "Migration of Tegula funebralis," Abstracts of Individual Problems, (Dillon Beach, Pacific Marine Station, unpublished report, 1966).

dates for the four-day low tide period, June 23-26, 1969.

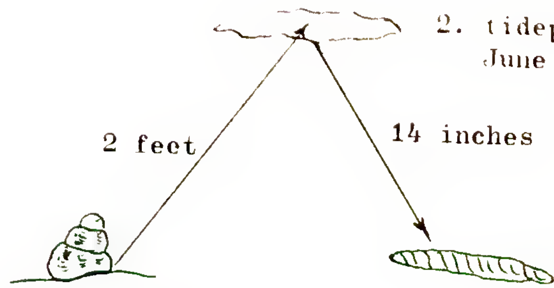

Figure 2. MOVEMENT OF TEGULA FUNEBRALIS

I assumed it moved from position 1 to 2 to 3 during the four days. On the other hand, since I was not at the reef to observe at high tides, this snail could have moved considerable distances when covered with water, or at nights, and rested at the spots where I found it during the daylight low tide hours.

3. Other Conclusions on the Base Counts

a. In general, the decreased base counts in sessile organisms is probably due to human collectors or natural ecological predators. When the base counts show a slight increase in sessile organisms, as in base counts 2 and 3 in area C for *Mytilus californianus*, the mussel, this is due to the improper placement of the square meter measuring device on the same transect line. These errors are especially probable when mussels are packed solid in their aggregate clusters.

b. The variations in sessile organisms from one base count to another may be attributed to collectors in a minor degree, but the mobility of the organisms accounts for the cyclical ups

and downs of the base count measurements.

c. The test statistics show some significant differences between each base count and between counts for each area (Appendix F):

(1) There is a significant difference in the population mean, μ, of organisms between areas A, B, and C.

Area A	Area B	Area C
$25.5/m^2$	$51.3/m^2$	$447.3/m^2$

The sample means above show that area C has the most abundant count of marine organisms per square meter, followed by area B, then area A.

In a previous report on the "Conservation of Marine Animals on Duxbury Reef, I wrote about the density of marine organisms in the three areas. Reef visitors walking over these same areas would see that the macroscopic animals are all gone from area A, e.g., seastars, red rock crabs, large mussels, goose barnacles, green sea anemones. The base counts also attest to the lack of such organisms in area A. Some extremities of area B are still relatively well populated with these macro-species, while in the outer portions of area C, the large adult specimens are <u>still</u> abundant. As recently as 1957, area A was still quite abundant with mussels and seastars. The 1969 base counts show only 1 to 3 seastars in the area A transects as compared to 50 seastars in the area C transects. Moreover, the mussel count per square is 1.6 for area A, in contrast to 421.9 for area C! Since seastars feed on mussels, there is a direct food chain relationship here. During the summer months, the mussel is quarantined because of the abundance of dinoflagellates, but in the winter and early spring, the mussel

gatherers are out in full force. If the current rate of collecting continues, within ten years the now abundant life in area C will closely resemble the present bleakness of areas A and B.

(2) Test statistics (Appendix F) also show a significant difference between base counts 1 and 2 in areas A and B, while the counts in area C remained essentially the same. Again, these decreases may be due to a combination of collectors, ecological predators, and mobility of organisms.

(3) Test statistics show no significant difference between base counts 1 and 3 in each area. Count 3 showed the same reduced numbers of sessile organisms as count 2 for areas A and B, a stability for these animals; however, the count 3 numbers for the more mobile animals was comparable to, and, in some cases, higher than count 1; these animals (snails) did move into some of the square meter plots to raise the count. Conservation education together with the ecological mobility of some marine animals favorably re-established the overall sample mean of base count 1.

Therefore, with conservation education, there appears to be a stability in the distribution of marine organisms and this confirms the major hypothesis stated on page 16.

(4) One future investigation that would prove interesting would be a comparison of these base counts in each area when and if Duxbury Reef becomes a "marine reserve" and the organisms are protected by law. Under these conditions, what would the base counts reveal?

E. ANALYSIS OF THE EFFECTS OF CONSERVATION EDUCATION ON SCHOOL GROUPS AND THE CORRELATIONS AND COMPARISONS OF ALL REEF VISITORS

1. The Effects of Conservation Instruction on School Classes

The principal hypothesis of the conservation education method of pre-test and post-test scores on five aspects of conservation behavior (pages 26-28, 61) is, given such instruction, school classes would display an improvement in conservation behavior on the reef.

Improvement in the post-test scores is shown in Graph S1 and S2, pages 61 and 62. For fifteen school classes consisting of 709 students and teachers, the overall results were:

	Total Score in points (500 possible points)	Average Percentage (100%)
Pre-test:	263.7	52.7%
Post-test:	406.7	81.3%
Improvement:	+143.0	+28.6%

There was a significant rise in total scores and average percentages on the post-test behavior results. This form of testing-- in which the examiner (1) presents five pre-test lecture type questions (2) grades the oral responses (3) then proceeds to observe and grade the actual behavior on the reef in regards to these conservation principles-- produced favorable results.

The test statistics for significant difference between pre-test and post-test scores may be seen in Appendix J. From this, we can conclude that conservation instruction in the reef habitat plays a significant role in promoting conservation behavior.

The key to success in this form of conservation presentation must be the examiner. The instruction must be presented in such a manner that the recipients will feel they are a part of the conservation movement. The scoring by the examiner may, however, be

biased: that is, he may desire such positive results that he scores the behavior of the class on the reef higher than the actual performance. To insure the best impartial results, I checked the post-test performance on five class scores submitted by my colleague examiner. My post-test scores did not differ from his by more than 10% on any one of the five questions. Therefore, I assume that within the rational judgment of at least two different examiners, the differences would not fluctuate more than 10% on each question.

In Graph S2, page 62, all school groups recorded an improvement in the post-test behavior scores (average percentage scores):

Elementary group improved 33.4%
Secondary group improved 9.0%
College group improved 28.0%

The secondary school improvement was lowest because one prominent high school class insisted on completing student project collections in area C despite the pre-test lecture (Table S1, page 63). I feel that in any area of natural beauty where conservation education is needed to protect the environment, at least 25% to 30% improvement in conserving behavior may be expected from school visitors.

2. <u>The Correlations and Comparisons of Data for all Reef Visitors</u>

This section attempts to "tie all the pieces" of remaining data together. The summary findings are as follows:

a. There is a definite correlation between the number of school collectors per year and the number of animals collected per year. The correlation of these numbers may be seen on Chart S1, page 65, covering the years 1961-1969. The correlation curve illustrates that with increasing numbers of school collectors, there will be a higher number of animals removed from the reef.

b. In the analysis of the experimental ten-week period consisting of the first five-week control period of no conservation education and the second five-week treatment period of conservation education, a significant difference is noted in the number of marine organisms removed from the reef per week (Chart S2, page 65).

In the control correlation curve, the more school collectors per week, the higher total number of organisms collected per week. The treatment correlation curve shows the opposite trend, the more school collectors per week, the lower the total animals collected per week!

c. Finally, conservation education, as instructed and presented through this project, definitely reduced the collecting done by general and school visitors to Duxbury Reef.

(1) With conservation instruction, the percentages of school visitors and general visitors who collect are greatly reduced, Chart S3, page 66.

	Percentage of Visitors Who Collect		
	Control Sample	Treatment Sample	Improvement (Reduction)
General visitors:	51.3%	24.3%	-27.0%
School visitors:	65.1%	19.4%	-45.7%

During the control period of no conservation education, several of the school classes visited the reef under the guidance of Bolinas Marine Station staff. For some years now, this marine laboratory staff has worked diligently to promote conservation education on the reef. In the control period, without the influence of specific conservation instruction of the treatment period, the school

visitors who were guided on the reef by Bolinas Marine Station staff showed only 25.2% who collected as compared to the overall 65.1% for all school visitors of the control period. Naturally, the treatment period enhanced the Bolinas laboratory program.

(2) Conservation education is also correlated with the average number of animals collected per collector (Chart S3b on page 66).

	Avg. No. of Animals Collected/Collector		
	Control	Treatment	Improvement
General visitors:	27.5	11.1	-16.4
School visitors:	5.1	2.1	3.0

Conservation instruction does reduce the average number of marine animals collected per collector. Notice in Chart S3b, page 66, that with instruction by the Bolinas Marine Station staff during the control period, the average number of animals collected was 1.5, even lower than the overall average of 2.1 for all school collectors in the treatment period!

The information provided in this research report does confirm the major and supporting hypotheses of this project, described on pages 16 and 17.

Conservation education does effectively reduce the collecting by visitors to the reef and promotes a stability in the distribution of marine organisms.

F. SUMMARY AND RECOMMENDATIONS

Duxbury Reef, the site of this research report is under extreme pressure from human beings. In a ten-week period, May 30 - August 7, 1969, there were 4,278 visitors to the three shale reef areas. In addition, approximately 257 other visitors dug clams in the Duxbury sandflats close to the town of Bolinas, area D on Appendix L, figure 1. For the first five weeks, a known total of 10,972 marine organisms was removed from the reef. The total does not take into account the many unrecorded thousands of other animals which were collected or killed on the reef. Include the buckets of seaweed, shells, rocks, agates, natural driftwood, boards, etc., and the volume is staggering.

The problem of abuse to the land exists because man does not respect nor love it enough (Leopold, page 3) to share it with anyone else. I have observed hundreds of people coming to the reef and abusing the reef. The problem is compounded by groups that are respected by the community. For example, under the control period of no conservation education, two professors of large universities arrived at the reef with their science students to collect marine organisms. The leaders of these groups knew of my efforts to protect and conserve Duxbury Reef. Even with this knowledge, they proceeded to dig into the reef to collect marine boring organisms; this activity is called "scientific investigation" by those who participate in it. So, when the students of these professors graduate, and 88% of these marine science students are eventually employed by academic institutions,[60] what form of conservation, if any, will they teach their students? History has

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[60] Andreas B. Rechnitzer, Marine Sciences in California Institutions of Higher Education, (State of California Coordinating Council for Higher Education, October, 1969), page IV-3.

shown that students will collect marine organisms, following the example of their professors or teachers: this geometric ratio colossus is often classified as "scientific inquiry." I started my teaching profession as one of these "justified" collectors and eventually I saw the damage of my own works. Thus, one of the goals of this report is to awaken and challenge other teachers, elementary through graduate school, to truly ponder the implications of their own actions.

This research report does illustrate that when school individuals practice conservation behavior on marine reefs, the number of persons collecting animals is reduced by about 45% and a stability in the distribution of marine organisms appears to take place, as seen in the sample transects. Marine biologist R. W. Castenholz has made studies which show that there is a natural interaction of ecological growth and stability within the intertidal communities if man does not intrude.[61]

1. Specific Recommendations

   a. Major marine intertidal reefs should be set aside as marine reserves. Methods to achieve this may be:

      (1) Special legislation initiated by state assemblymen to cover specific reef areas, such as the Duxbury Reef Reserve. This method has already been implemented in the state of California to create marine reserves in Southern California (i.e., Dana Point, Heister Point, etc.). This method is slow and piecemeal and is generally initiated by local interest groups.

      (2) Placement of all invertebrates under the State Fish and Game Commission. In California, under state regulation

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[61] R. W. Castenholz, "Stability and Stresses in Intertidal Populations," Pollution and Marine Biology, (New York: John Wiley and Sons, 1967) pp. 15-28.

SB 858, invertebrates are classified as "fish" and may be prohibited from removal under this law. This method, though practical, is slow and may be subject to political maneuvers from local communities up to higher state levels. Current negotiations to save Duxbury Reef seem to be heading in this direction. The rationale to list invertebrates at Duxbury Reef as "fish" will have to be justified at the local county level, the Board of Supervisors, then be passed at the state level by the State Fish and Game Commission. Again, this method is piecemeal, and does not include other natural areas within the state that may be just as valuable as Duxbury Reef.

(3) Establishment of a statewide Commission on Marine Coastal Environments, which would develop a master plan for the state reserves and developments. U. S. Senator Alan Cranston has already called for a coastline master plan.

From observation of previous politically-influenced committees, the proposed commission mentioned above may become bogged down with much red-tape and the years may accumulate rapidly before legislation is accomplished. However, under the State Department of Parks and Recreation, a special committee on underwater parks has effectively brought about legislation of three underwater parks: La Jolla in San Diego, Big Sur in Monterey, and Salt Point in Sonoma County. I have been thoroughly impressed with this committee's efficiency!

Two years ago, the Coordinating Council of Higher Education polled their academic institutions to determine

which marine area each school would like to have for educational purposes. Thirty-nine universities and colleges claimed nearly every inch of California's coast and made choices which overlapped in many metropolitan areas. The California State Land Commission reviews these requests, but I fear that it may be years before some master plan can be worked out.

(4) Private purchases of land. The University of California Board of Regents has purchased land and water reserves throughout the state for future preservation, observation, and research. Perhaps this system can be expanded by extending state funds to the Board of Regents for additional purchases.

Likewise, local nature conservation groups may organize together to form a united front for purchasing natural environments as reserves. Newspapers recently reported some action along this line from San Jose State College.

(5) Finally, through federal legislation, marine intertidal habitats may be included into the Federal Wilderness Act and be set aside by government authorities. Recently, the House of Representatives approved a bill to create a Presidential Advisory Council on preservation of the nation's natural environments by a vote of 372 to 15. The council would compile data on all use, misuse and abuse of water, atmosphere, forest, wildlife, marine life and other natural resources. I hope that my research report will provide this council much insight.

b. <u>All organic and inorganic materials within marine reserves should be protected.</u>

The Pt. Lobos Reserve State Park is a good example of what I would recommend for a marine reserve. No collecting or removal of any organic or inorganic material is allowed from the reserve. Ecologists have long recognized the balance of biotic and abiotic factors in an environment-- animals, plants (seaweeds), wood, rocks, water, etc. These factors all interact in an ecological web. Such balance of living and non-living materials must be maintained for all to enjoy.

Specifically, I am recommending that no animals, plants, rocks (agates), driftwood, or other objects be removed from within the proposed boundaries of the Duxbury Reef Reserve. The reef should be open to fishermen after the true fish, but the bait used should be brought in from outside the reef. Through the issuance of special permits by the reserve authorities, scientific representatives may study the organisms and areas for the benefit of man. Collecting for the purpose of taxonomic classification and museum displays should be by permit only.

Even the walking by people on the reef destroys marine life. On July 2, 1969, in area A of Duxbury Reef, I took ten steps on the flat reef and observed that under each step I squashed and killed on the average ten tiny periwinkles, <u>Littorina scutulata</u>. On this same day, the low tide was a -1.6 at about 7:45 A.M. (Photo 1). Only my wife and daughter were on the reef to help count the transect organisms. Two hours later, there were about 280 people on this same reef, 70 of whom can be seen in Photo 2. Without collecting one periwinkle into a

bucket, man crushed an unknown number under his "stomping" feet that day.

Some funds should be allocated from a local budget, school or county, to implement the further study and monitoring of the density of marine organisms. The work in this research report should be carried on for a number of years to add to this new knowledge of marine reefs. Furthermore, similar studies should begin on other reefs throughout California for comparisons to the Duxbury Reef data.

c. The Duxbury Reef Reserve boundaries and maintenance

The Duxbury Reef boundaries should extend from the Pt. Reyes National Seashore boundary at Palomarin Reef, south along the intertidal coast to area C of the main Duxbury Reef. A low one-foot concrete wall should be erected between area D and area C to designate the beginnings of the Duxbury Reef Reserve (Appendix L, figure 1). Other signs should be posted at appropriate locations to inform the public of the laws and regulations governing the use of the reserve.

The control and authority of the reserve should be under the jurisdiction of the Marin County Parks and Recreation Department until the state with sufficient finances can make the reserve a part of a coastal state park system. A committee comprised of local representatives of education, conservation, and civic groups should act in an advisory capacity to assist the Parks and Recreation Department.

d. Conservation education should be developed in the schools through new state financing.

Already there has been an advisory panel urging the

California State Board of Education to push for finance to develop outdoor classrooms and accelerate the teaching of conservation education in public schools. I consider this step imperative in halting the depletion of our natural resources. Through local school districts, coordinated committees should be established to set up outdoor laboratories, specifically one at Duxbury Reef and Bolinas Lagoon to provide ecology and conservation education to school and general public visitors. Certainly, the small conservation model initiated by the Bolinas Marine Station staff and this research study of the effect of conservation instruction at the reef have paved the path of success in preserving this marine environment-- the model now needs to be expanded!

2. Brief Summary

   a. Duxbury Reef is undergoing constant depletion of marine organisms.

   b. The number of reef visitors has increased every year and now total about 2,000 per month for the peak months of low tides. For the first ten months of 1969, 830,000 persons visited the Pt. Reyes National Seashore Park. The prediction is that visits to this area will increase manyfold. Duxbury Reef sits at the edge of this magnificent park and with its 66 acres, it is the largest shale reef in North America-- it will receive its share of increasing numbers of visitors.

   c. The reef is divided into three study areas, A,B, and C (Appendix L, figure 1; page 20). About 88% of all visitors visit area A, while only 7% visit area C. Area A is depleted of many marine animals, and area C is rich with a high density and

diversity of marine life. Eventually, more people will venture out into area C to collect the abundant marine life. If there is no control over the current rate of collecting, 15 animals per collector, I predict that within ten years, the now abundant life of Area C will be reduced to the present barrenness of area A.

d. Up to this time, available data on what occurs on marine intertidal reefs was nil. This research report's major contribution is to analyze all the activities within a ten-week period with a first five-week control period of no conservation education and a second five-week treatment period of conservation education at the reef. This latter five-week period showed a greatly reduced percentage of visitors who collect and a reduced average number of organisms collected per collector.

e. The major recommednation of this report is to establish a marine reserve at Duxbury Reef with no collecting of organic and inorganic materials permitted, but allowing individuals to fish under State Fish and Game regulations.

"O Lord, how manifold are thy works!
In wisdom hast thou made them all;
the earth is full of thy creatures.

Yonder is the sea, great and wide,
which teems with things innumerable,
living things both small and great."

-Psalm 104: 24,25

Today is not too late to save the remnant!

The End

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APPENDIX A — STATISTICAL FORMULAE

TERMINOLOGY

Sample refers to the groups of individuals under study. The sample is but a representative "specimen" or portion, randomly selected, of a much larger total group called the population.

Population, as noted above, refers to the total aggregation of a species of individuals in a statistical study. In this dissertation, population statistics are based on data collected from the sample.

Mean refers to the average of all measurements.

Proportion refers to the percentage portion (in decimal form) of the sample having a certain characteristic (successes) or NOT having a certain characteristic (failures).

Difference refers to the difference between two measurements which were made on the same individual.

SYMBOLS

	For the Sample	For the Population
Mean	$\bar{X} = \frac{\sum x_i}{n} = \frac{\text{sum of all measurements } (x_1 + x_2, \ldots + x_n)}{\text{Number in the sample } (n)}$	μ
Proportion	$\hat{p} = \frac{\text{number of successes}}{\text{number in sample}}$	p
	$\hat{q} = \frac{\text{number of failures}}{\text{number in sample}}$ $\hat{p} + \hat{q} = 1.00$	q
Mean of the Differences	$\bar{d} = \frac{\sum d_i}{n} = \frac{\text{sum of all differences}}{\text{number in sample}}$	d
Variance	$s^2 = \frac{n \sum x_i^2 - (\sum x_i)^2}{n(n-1)}$	σ^2
Standard Deviation	$s = \sqrt{\text{variance}}$	σ
(subscripts)	o = pooled or common for two or more samples, such as pooled variance or pooled proportion	

FORMULAE

Data from the sample may be interpreted in terms of the population by use of statistical formulae and tables, Z table for $n \geq 30$, t for $n < 30$.

For Population Mean

The 95% confidence interval is used consistently in this dissertation to determine the interval within which we expect the population mean to be. If, on the basis of repeated sampling, many 95 % confidence intervals for μ are set up, then approximately 95 % of these confidence intervals will actually contain the true mean, μ .

(Appendix A) Statistical Formulae - continued

For sample size less than 30: $\alpha = .05$

$$P\left(\bar{X} - t_{\frac{\alpha}{2}, n-1} \frac{s}{\sqrt{n}} < \mu < \bar{X} + t_{\frac{\alpha}{2}, n-1} \frac{s}{\sqrt{n}}\right) = 1 - \alpha$$

For sample size equal to or greater than 30: $\alpha = .05$

$$P\left(\bar{X} - Z_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}} \leq \mu \leq \bar{X} + Z_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}}\right) = 1 - \alpha$$

For Testing Hypotheses

1. Using the mean

Test statistic: $Z = \dfrac{\bar{X}_1 - \bar{X}_2 - (\mu_1 - \mu_2)}{\sqrt{\dfrac{(s_1)^2}{n_1} + \dfrac{(s_2)^2}{n_2}}}$

If H_0 is rejected, interval estimate of $\mu_1 - \mu_2 =$

$$\bar{X}_1 - \bar{X}_2 \pm Z_{\frac{\alpha}{2}} \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

2. Using the proportion

Test statistic: $Z = \dfrac{\hat{p}_1 - \hat{p}_2 - (p_1 - p_2)}{\sqrt{\hat{p}_o \hat{q}_o \left(\dfrac{1}{n_1} + \dfrac{1}{n_2}\right)}}$ which is distributed as $N(0,1)$ when H_0 is true.

If H_0 is rejected, interval estimate of $p_1 - p_2 =$

$$(\hat{p}_1 - \hat{p}_2) - Z_{\frac{\alpha}{2}} \sqrt{\frac{\hat{p}_1\hat{q}_1}{n_1} + \frac{\hat{p}_2\hat{q}_2}{n_2}}$$

3. Using the mean of difference

Test statistic: $Z = \dfrac{\bar{d} - \alpha_d}{s_d/\sqrt{n}}$

If we reject H_0, confidence interval of $\mu_d = \bar{d} \pm Z_{\frac{\alpha}{2}} \dfrac{s_d}{\sqrt{n}}$

Test with confidence interval: (95%)

$$\bar{d} - t_{\frac{\alpha}{2}, n-1} \frac{s_d}{\sqrt{n}} \leq \mu_d \leq \bar{d} + t_{\frac{\alpha}{2}, n-1} \frac{s_d}{\sqrt{n}}$$

If interval crosses, conclude that there is no difference between the two sets of measurements.

APPENDIX B

PHYSICAL MEASUREMENTS

	CONDUCTIVITY		TEMPERATURE C°		SALINITY o/oo		OXYGEN ml/liter	
	x_i	x_i^2	x_i	x_i^2	x_i	x_i^2	x_i	x_i^2
AREA A								
6/12/69	38.1	1451.61	13.4	179.56	31.6	998.56	2.61*	6.81
6/29/69	39.8	1584.04	11.45	131.10	34.8	1211.04	2.35**	5.52
7/3/69	40.6	1648.36	12.5	156.25	34.7	1204.09	2.21	4.88
7/13/69	39.6	1568.16	12.8	163.84	33.5	1122.25	-	-
	158.1	6252.17	50.15	630.75	134.6	4535.94	7.17	17.21
$s^2 =$	1.0891		.6647		2.2166		.0368	
$s =$	1.0435		.8152		1.4888		.1918	
AREA B								
6/12/69	37.8	1428.84	13.4	179.56	31.5	992.25	2.99*	8.94
6/29/69	39.8	1584.04	11.5	132.25	34.8	1211.04	2.33	5.43
7/3/69	40.2	1616.04	11.9	141.61	34.4	1183.36	2.71	7.34
7/13/69	39.7	1576.09	12.8	163.84	33.4	1115.56	-	-
	157.5	6205.01	49.6	617.26	134.1	4502.21	8.03	21.71
$s^2 =$	1.1491		.7400		2.1691		.1081	
$s =$	1.0719		.8602		1.4727		.3287	
AREA C								
6/12/69	38.9	1513.21	13.1	171.61	31.9	1017.61	2.82*	7.95
6/29/69	38.9	1513.21	10.76	115.78	34.7	1204.09	2.48	6.15
7/3/69	39.36	1549.21	11.2	125.44	34.6	1197.16	2.91	8.47
7/13/69	39.4	1552.36	12.5	156.25	33.5	1122.25	-	-
	156.56	6127.99	47.56	569.08	134.70	4541.11	8.21	22.57
$s^2 =$	.0772		1.1972		1.6958		.0509	
$s =$	.2778		1.0941		1.3022		.2256	

* sample taken on 6/17/69
** sample taken on 8/5/69

Complete and return this form immediately to:

Gordon Chan
College of Marin
Kentfield, Calif 94904

INVENTORY SURVEY of Educational Classes
to Duxbury Reef, Bolinas, California

Name of School District ________________ School ____________________

School Address ____ Zip ________

Teacher's Name (optional) ____

Grade/s you teach __________ Subject matter relating to Duxbury ________________

No. of years teaching in this school district __________

Teacher's summer mailing address:

____

____

Please give the most accurate estimates for your answers below:

1. How many years have you visited Duxbury Reef with your classes on field trips? ______
2. Write the time span of your years at Duxbury (e.g., 1965-1969) ____________________
3. No. of trips each year: 1961 ____ 62 ____ 63 ____ 64 ____ 65 ____ 66 ____ 67 ____ 68 ____ 69 ____
4. No. of students for all trips each year: 1961 ____ 62 ____ 63 ____ 64 ____ 65 ____ 66 ____ 67 ____ 68 ____ 69 ____
5. What is the average number of times you visit the following special areas on Duxbury Reef per year? (see attached map) Area A ________ Area B ________ Area C ________
6. Estimate the approximate total number of marine animals (as listed below) your classes have collected each year from Duxbury Reef:

Marine Animals	1961	1962	1963	1964	1965	1966	1967	1968	1969
Sea anemones									
Chitons									
Mussels									
Rock clams									
Limpets									
Snails									
Hermit crabs									
Other crabs									
Starfish (seastars)									
Sea urchins									
Fish									
Seaweeds (yes or no)									

7. Check the most appropriate statement describing the purpose of educational field trips to Duxbury:

   ______ a. Collections are made for classroom studies- labs, aquaria, etc.

   ______ b. Collections are made for individual projects.

   ______ c. Collections are made to build a museum display.

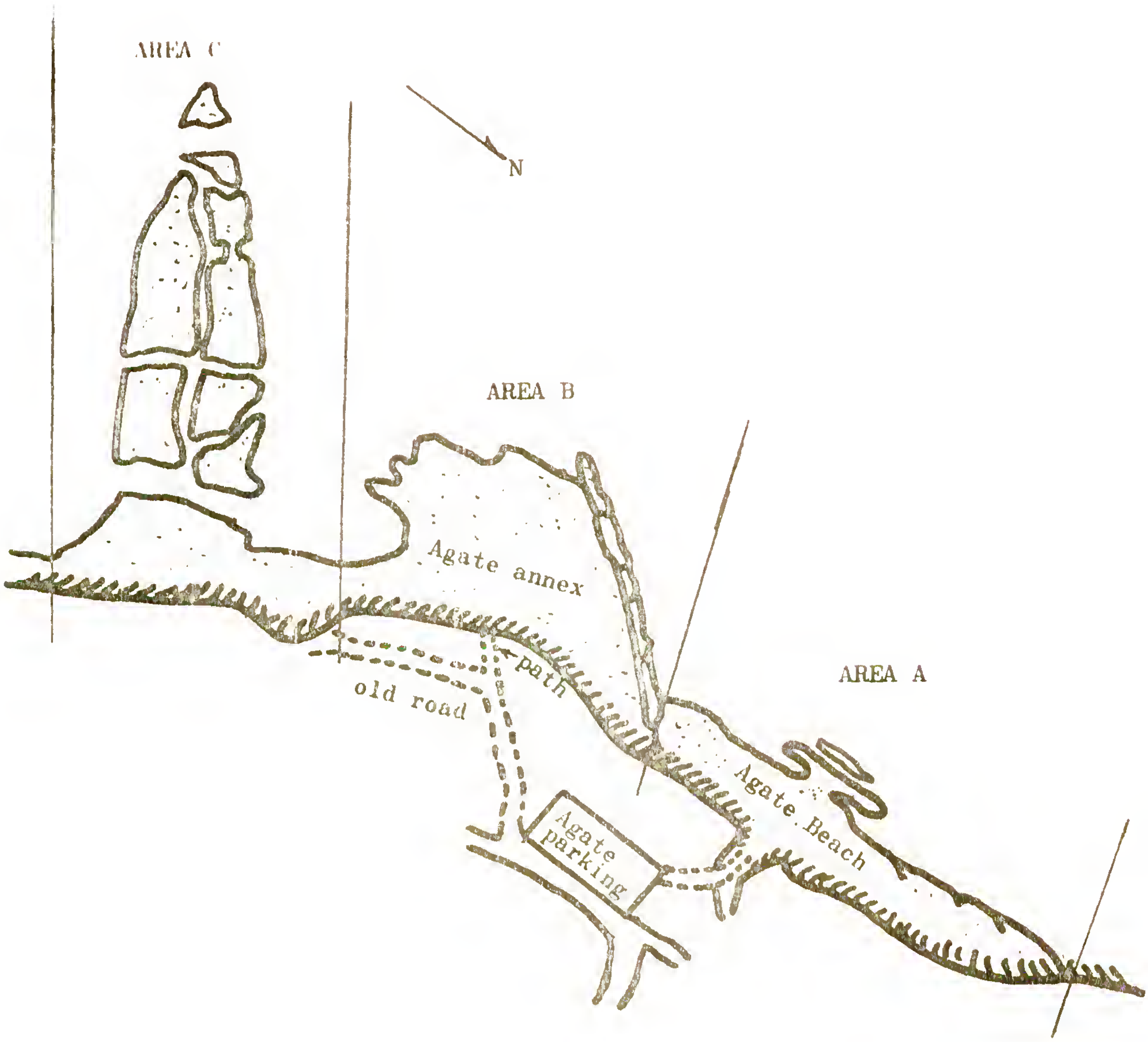
   ______ d. Collections are made to stimulate pupil interest.

   ______ e. Other reasons ________________________________

8. Describe briefly your major emphasis in the teaching of marine science units at the seashores: (use other side of paper)

MAP - DUXBURY REEF INTERTIDAL STUDY AREAS

(not drawn to scale)



APPENDIX D

TEST STATISTICS: PROPORTION OF SCHOOL COLLECTORS

Control Sample
Weeks I - V
May 30 - July 3

1. Question: Is there any difference between the proportion of school visitors and the proportion of general visitors who collect on the reef?

Let $\hat{p}_1$ = proportion of school collectors = .651
$\hat{p}_2$ = proportion of general collectors= .513

Hypothesis- H_0: $p_1 = p_2 = p_0$ H_1: $p_1 \neq p_2$ $\alpha = .05$

Reject H_0 if $Z \geq 1.96$ or $Z \leq -1.96$

Conclusion: $Z = 7.08$. Reject H_0. The proportion of school visitors who collect is greater than the proportion of general visitors who collect on the reef. The interval estimate of difference is-

$$.100 \leq p_1 - p_2 \leq .176 \quad \text{(or 10.0\% to 17.6\%)}$$

2. Question: Is there any difference in the proportion of collecting by the elementary, secondary and college school groups?

Let $\hat{p}_1$ = proportion of elementary school collectors = .694
$\hat{p}_2$ = proportion of secondary school collectors = .263
$\hat{p}_3$ = proportion of college school collectors = .828

Hypothesis- H_0: $p_1 = p_2 = p_3$ H_1: $p_1 \neq p_2 \neq p_3$ $(p_1 \neq p_2,\ p_2 \neq p_3,\ p_1 \neq p_3)$

Reject H_0 if $Z \geq 1.96$ or $Z \leq -1.96$

Conclusion: For p_1 and p_2, $Z = 11.02$, thus $p_1 \neq p_2$

For p_2 and p_3, $Z = -9.59$, thus $p_2 \neq p_3$

For p_1 and p_3, $Z = -3.09$, thus $p_1 \neq p_3$

Reject H_0. There is a difference between the proportions of collecting by the three school groups (elementary, secondary, and college) who visit the reef. The interval estimates of difference are:

$$.361 \leq p_1 - p_2 \leq .501$$

$$-.658 \leq p_2 - p_3 \leq -.472$$

$$-.206 \leq p_1 - p_3 \leq -.062$$

The proportion of college visitors who collect is greater than the proportion of elementary visitors who collect, which in turn is greater than the proportion of secondary visitors who collect.

The college proportion is 6.2% to 20.6% (inclusive) greater than the elementary proportion, which is 36.1% to 50.1% (inclusive) greater than the secondary proportion.

The college proportion is 47.2% to 65.8% (inclusive) greater than the secondary proportion.

APPENDIX E

TEST STATISTICS: PROPORTION OF SCHOOL COLLECTORS

Treatment Sample
Weeks VI - X
July 4 - August 7

1. Question: Is there any difference between the proportion of school visitors and the proportion of general visitors who collect on the reef?

Let $\hat{p}_1$ = proportion of school collectors = .194
$\hat{p}_2$ = proportion of general collectors= .243

Hypothesis- $H_0: p_1 = p_2 = p_0$ $\quad H: p_1 \neq p_2$ $\quad \alpha = .05$

Reject H_0 if $Z \geq 1.96$ or $Z \leq -1.96$

Conclusion: $Z = -2.48$. Reject H_0. The proportion of school visitors who collect is less than the proportion of general visitors who collect on the reef. The interval estimate of difference is-

$$-.088 \leq p_1 - p_2 \leq -.010 \text{ (or 1.0\% to 8.8\% inclusive)}$$

2. Question: Is there any difference in the proportion of collecting by the elementary, secondary and college school groups?

Let $\hat{p}_1$ = proportion of elementary school collectors = .132
$\hat{p}_2$ = proportion of secondary school collectors = .414
$\hat{p}_3$ = proportion of college school collectors = .281

Hypothesis- $H_0: p_1 = p_2 = p_3; H_1: p_1 \neq p_2 \neq p_3$ $(p_1 \neq p_2, p_2 \neq p_3, p_1 \neq p_3)$

Reject H_0 if $Z \geq 1.96$ or $Z \leq -1.96$

Conclusion: For p_1 and p_2, $Z = -7.91$, thus $p_1 \neq p_2$

For p_2 and p_3, $Z = 2.32$, thus $p_2 \neq p_3$

For p_1 and p_3, $Z = -4.35$, thus $p_1 \neq p_3$

Reject H_0. There is a difference between the proportion of collecting by the three school groups (elementary, secondary, and college) who visit the reef. The interval estimates of difference are:

$$-.367 \leq p_1 - p_2 \leq -.196$$

$$.022 \leq p_2 - p_3 \leq .244$$

$$-.229 \leq p_1 - p_3 \leq -.069$$

The proportion of secondary school visitors who collect is greater than the proportion of college visitors who collect, which in turn is greater than the proportion of elementary school visitors who collect.

The secondary proportion is .022 (2.2%) to .244 (24.4%), inclusive, greater than the college proportion, which is .069 (6.9%) to .229 (22.9%), inclusive, greater than the elementary proportion.

The secondary proportion is 19.6% to 36.7% inclusive greater than the elementary proportion.

APPENDIX F

TEST STATISTICS

AREA AND BASE COUNT COMPARISONS OF THE NUMBER OF ORGANISMS PER SQUARE METER (SIX SPECIES)

DATA	AREA A (μ_1)	AREA B (μ_2)	AREA C (μ_3)
Base Count 1	25.5 m^2	51.3/m^2	447.3/m^2
95% confidence interval	$20 \leq \mu_1 \leq 31$	$37 \leq \mu_2 \leq 66$	$250 \leq \mu_3 \leq 645$
Base Count 2	17.7/m^2	30.6/m^2	453.9/m^2
95% confidence interval	$13 \leq \mu_1 \leq 23$	$23 \leq \mu_2 \leq 38$	$251 \leq \mu_3 \leq 641$
Base Count 3	27.2/m^2	49.7/m^2	445.7/m^2
95% confidence interval	$21 \leq \mu_1 \leq 33$	$41 \leq \mu_2 \leq 59$	$242 \leq \mu_3 \leq 634$

Statistical Comparison of Mean of Organisms between Areas A,B,C (using Base Count 1)

Question 1: Is there any difference in the mean of organisms in areas A,B,C?

TEST for H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_0$ H_1: $\mu_1 \angle \mu_2 \angle \mu_3$

$\alpha = .05$ Reject H_0 if $Z \angle -1.645$

Z value: For H_0: $\mu_1 = \mu_2$, $Z = -3.2$ For H_0: $\mu_2 = \mu_3$ $Z = -3.9$ For H_0: $\mu_1 = \mu_3$ $Z = -4.2$

CONCLUSION: Reject H_0. Population mean of organisms/m^2 in Area A is less than that in Area B, which in turn is less than that in Area C. Area C has the most abundant count for the six species; Area A has the least.

Interval estimate of difference: $10.1 \angle \mu_1 - \mu_2 \angle 41.6$ $198.2 \angle \mu_2 - \mu_3 \angle 593.7$ $224.5 \angle \mu_1 - \mu_3 \angle 619.0$

Effect of Conservation Education on the Count of Organisms per Square Meter

Question 2: Is there any difference in the population mean between Base Counts 1 and 2 in each area when there is no conservation education?

TEST for H_0: $\mu_{\text{Area A}_1 \text{ count } 1} = \mu_{\text{Area A}_2 \text{ count } 2}$ OR H_0: $\mu_d = 0$ (mean of difference) H_1: $\mu_d \neq 0$

$\alpha = .05$ Reject H_0 if $Z > 1.96$ or $Z \angle -1.96$

Z value: Area A: 3.33 Area B: 4.63 Area C: -1.15

CONCLUSION: Reject H_0 for Areas A and B only. Do not reject H_0 for Area C. The population means/m^2 for Areas A and B have reduced from Base Count 1 to Base Count 2. Visitor collecting due to lack of conservation education affects the population means in Areas A and B. The count in Area C remains essentially the same.

Interval estimate of difference: (reduction in population mean from base count 1 to base count 2)

For area A-	For area B-	For area C-
$12.05 \angle \mu_d \angle 21.25$	$16.07 \leq \mu_d \leq 25.33$	(no significant difference)

(Appendix F -- continued)

AREA AND BASE COUNT COMPARISONS - continued

Question 3: Is there any difference in the population mean between Base Counts 1 and 3? Will the count of animals (Base Count 3) return to the original population mean (Base Count 1) after five weeks of conservation education?

TEST for H_o: $\mu_1 = \mu_3$ (for each area) OR H_o: $\mu_d = 0$ H_1: $\mu_d \neq 0$

$\alpha = .05$ Reject H_o if $Z \geq 1.96$ or $Z \leq -1.96$

Z value: Area A: -.514 Area B: 0.029 Area C: 0.378

CONCLUSION: Do not reject H_o for areas A, B, and C. There is no difference between Base Counts 1 and 3 in all three areas. Therefore, the organism count of Base 3 did return to the count of Base 1. Conservation education does enhance the re-establishment of the population mean of marine organisms through reduced collecting (shown on Tables C9 and T9, page 52.)

APPENDIX G TEST OF CONSERVATION EDUCATION

In all tests of hypotheses below, $\hat{p}_1$= proportion in the control sample;
$\hat{p}_2$= proportion in the treatment sample.

REEF VISITORS

Question: Are the two samples similar in proportion of school visitors? ($\hat{p}_1$= .544, $\hat{p}_2$=.551)

TEST H_0: $p_1 = p_2$; H_1: $p_1 \neq p_2$ Reject H_0 if $Z \geq 1.96$ or $Z \leq -1.96$

Conclusion: $Z = -0.453$. Do not reject H_0. There is no significant difference between the proportions of school visitors in control and in treatment.

COLLECTORS

Question 1: Does conservation education (treatment) reduce the proportion of visitors who collect? ($\hat{p}_1$= .588, $\hat{p}_2$= .216)

TEST H_0: $p_1 = p_2$; H_1: $p_1 \geq p_2$ Reject H_0 if $Z \geq 1.645$

Conclusion: $Z = 24.165$. Reject H_0. The proportion of control visitors collecting is higher than the proportion of treatment visitors collecting by an interval estimate of difference of $34.5\% \leq p_1 - p_2 \leq 39.9\%$.

Question 2: Does conservation education reduce the proportion of school visitors who collect? ($\hat{p}_1$= .681, $\hat{p}_2$= .194)

TEST H_0: $p_1 = p_2$; H_1: $p_1 \geq p_2$ Reject H_0 if $Z \geq 1.645$

Conclusion: $Z = 22.045$. Reject H_0. The proportion of control school visitors collecting is higher than the proportion of treatment school visitors collecting by an interval estimate of difference of $42.2\% \leq p_1 - p_2 \leq 49.2\%$.

Question 3: Does conservation education reduce the proportion of general visitors who collect? ($\hat{p}_1$= .513, $\hat{p}_2$= .243)

TEST H_0: $p_1 = p_2$; H_1: $p_1 \geq p_2$ Reject H_0 if $Z \geq 1.645$

Conclusion: $Z = 11.96$. Reject H_0. The proportion of control general visitors collecting is higher than the proportion of treatment general visitors collecting by an interval estimate of difference of $22.9\% \leq p_1 - p_2 \leq 31.1\%$.

APPENDIX II

DUXBURY REEF SURVEY FORM

Report by ______________

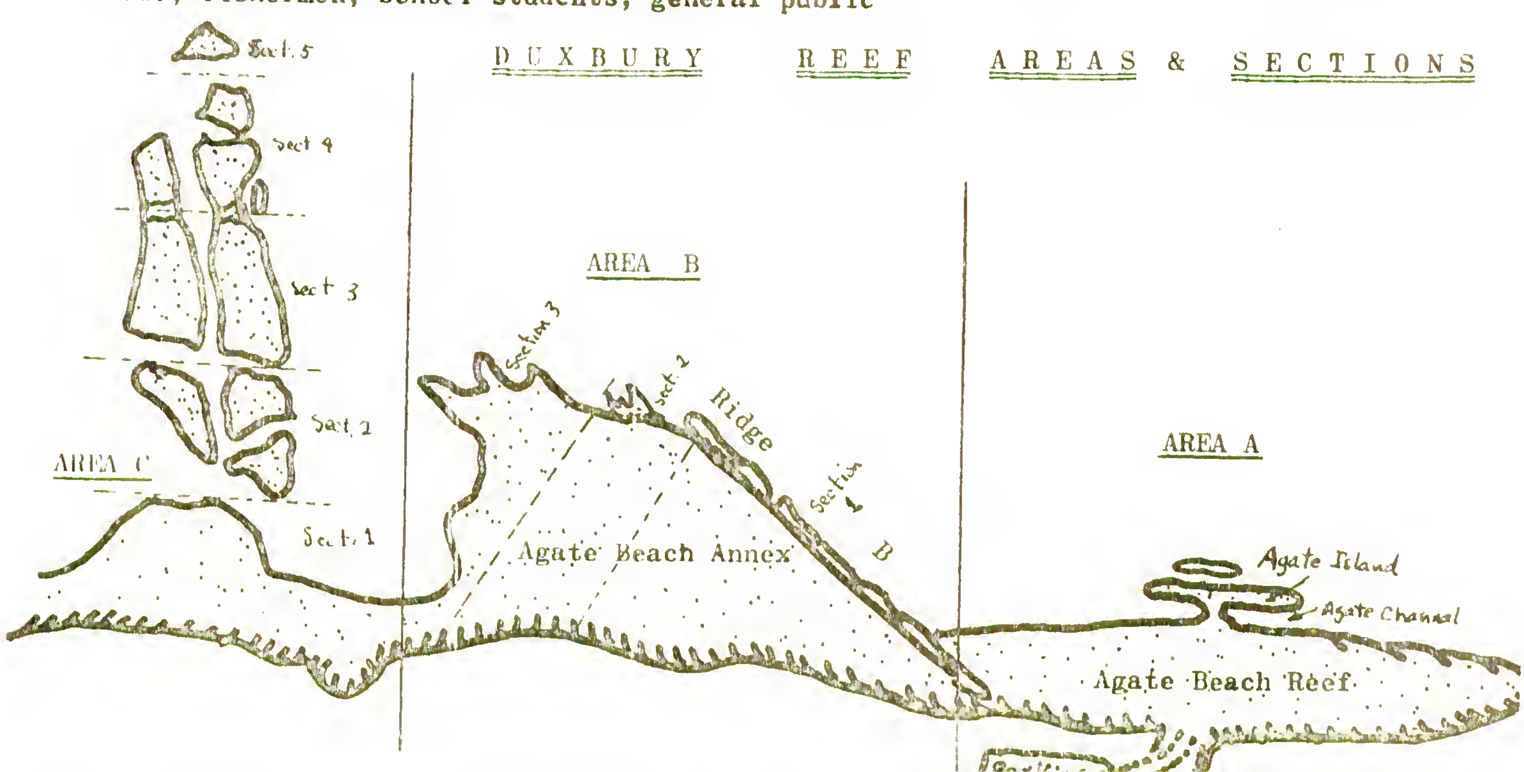
Total hours on reef ______

DATE ______________ TIDE ____________ TIME of TIDE ______________

PEOPLE* Name type and where they come from	Number of people in the group	Area of Duxbury visited	Activity of the people	Names of: Organisms Collected	Number of organism
TOTALS–					

* i.e., fishermen, school students, general public

DUXBURY REEF AREAS & SECTIONS



APPENDIX I DUXBURY REEF - SCHOOL BEHAVIOUR OBSERVATIONS TEST

- G. Chan

School Address ____________________ Teacher's Name ____________________ Date of Reef Visit __________

Tide and Time __________

When did teacher first visit the reef __________(year)

Time on Reef __________ A.M.or P.M.

Avg. no. of times the teacher visits Duxbury each year __________

Reef Area Visited (A,B,C) __________

Directions: Record Pre-test % for questions first before discussing conservation items

SCORE	Pre-test % Total Class	TEST ITEMS	Post-test % of Class Performance on Reef	SCORE
		1. Do not collect living marine organisms. Pre-test Question: How many of you have ever taken live marine animals from the seashore to the home or to the school for observation, etc.? Post-test Q: % estimate of class which did not collect organisms (include data of collection)		
		2. If marine animal is picked up, replace it in its exact niche. Pre-Q: How many of you, after picking up a seastar, would replace it in the nearest tidepool?		
		3. Turn the rock back over to its original position. Pre-Q: If a crab scurried under a rock, how many of you would turn the rock over, pick up the crab and run to show your classmates what you had found?		
		4. Do not tear up seaweed or rocky substrate to get at animals. Pre-Q: How many of you would pull up a seaweed to find the crab that scurried underneath its holdfast?		
		5. Walk carefully on the reef; disturb the least amount of marine life. Pre-Q: After coming on a reef, if you spotted a sea lion, how many of you would run quickly to see if it were alive or dead?		

APPENDIX J TEST FOR SIGNIFICANCE OF CONSERVATION INSTRUCTION

(All School Groups)

TEST for difference in conservation behavior due to conservation instruction.

Procedure: Correlation of conservation test observations (or Matched pairs) and Estimation (by 95% confidence interval) of the average population difference, μ_d, between pre-test and post-test average percentage scores.

School Group	Class n_i	Average Percentage Pre-test score	Average Percentage Post-test score	Difference d_i	d_i^2
Elementary	n_1	88	72	-16	256
	n_2	81	94	13	169
	n_3	72	86	14	196
	n_4	62	96	34	1156
	n_5	62	72	10	100
	n_6	24	88	64	4096
	n_7	23	55	32	1024
	n_8	4	70	66	4356
	n_9	2	86	84	7056
Secondary	n_{10}	97	79	-18	324
	n_{11}	46	82	36	1296
College	n_{12}	84	90	6	36
	n_{13}	75	81	6	36
	n_{14}	44	86	42	1764
	n_{15}	27	77	50	2500
		791	1214	423	24365

$\sum d_i = 423$ = sum of the differences

$\sum d_i^2 = 24365$ = sum of each squared difference

$\bar{d} = 423 \div 15 = 28.2$ = avg. sample difference

s_d^2 = variance of the differences= $\dfrac{n\sum d^2 - (\sum d)^2}{n(n-1)} = 888.31$

s_d = standard deviation of the differences= 29.81

95% confidence interval for the average population difference:

$$\bar{d} - t_{\frac{\alpha}{2}}(n-1)\frac{s_d}{\sqrt{n}} \leq \mu_d \leq \bar{d} + t_{\frac{\alpha}{2}}(n-1)\frac{s_d}{\sqrt{n}}$$

$$28.2 - 2.15(7.70) \leq \mu_d \leq 28.2 + 2.15(7.70)$$

$$11.7 \leq \mu_d \leq 44.8$$

Conclusion: Since the interval does not cross 0, we can conclude that there is a significant difference between the pre-test and the post-test scores, that the performance on the post-test was superior to that on the pre-test. Therefore, we can assume that conservation instruction plays a significant role in promoting conservation behavior.

Summary of Conservation Questionnaire on Duxbury Reef

Treatment Period
Week VI - X
July 4 - August 7

42 Responses

32 from Marin County
9 Outside of Marin County

30 School Teachers
11 General Public

22 made their visits to Duxbury from 1966-1969
10 " " " " " " 1954-1965

30 visited the reef 1-5 times per year
6 " " " 6-21 " " "

37 agreed that man on the Reef is a "predator-hunter" of marine organisms
1 said man is a farmer
3 had other opinions

25 stated that Areas A and B are the most visited
18 " " Area C was the the least visited
11 no opinion

41 agreed that marine life will eventually be destroyed on the reef if there is no control or restrictions.

40 stated that they were already conservationist
11 would change their behaviour from a collector to a conservationist on the basis of the information presented on Duxbury Reef
1 would not change his behaviour from a collector status

39 agreed that Duxbury Reef should be a marine reserve

35 favored setting other coastal areas as marine reserves

Opinions on the type of marine reserve:

0 wanted no restrictions on collecting marine organisms
12 favored collecting with special permits
8 favored collecting in accordance with State Fish and Game Codes
25 stated that NO collecting be done on such reserves.

To the Reader: If you are concerned about Duxbury Reef, please check the appropriate boxes below, and then deposit this questionnaire in the adjacent slotted box or mail it to the sponsors below.

(Appendix K-- continued)

Thank you.

Check your status:

- Adult ☐
- H.S. student ☐
- Elem. student ☐

Are you a school teacher? yes______ no______

What town or community do you come from ? ________________

How often do you visit the reef each year?________ Since?______ yr.

1. Which definition describes the activities of man on Duxbury Reef? A "predator-hunter" removes and never replaces, while a "farmer" replenishes the product.

   He is a predator-hunter: ☐
   He is a farmer: ☐
   Other________________

2. Classify the Areas of Duxbury Reef according to number of visitors. Use: 1 = most visitors
   2 = second with visitors
   3 = least visitors

   (you may refer to page 1)

   Areas: A ☐
   B ☐
   C ☐
   no opinion: ☐

3. If the unrestricted damage (pages 1-3) by man is permitted to continue over the years, would you agree that the balance of marine life in these areas would be eventually destroyed?

   Yes ☐
   No ☐
   no opinion ☐

4. On the basis of the information given in this paper, will you change your behaviour from that of a collector to one of conservationist?

   Check here if you are already a conservationist ☐

   Yes ☐
   No ☐
   no opinion ☐

5. Since Duxbury Reef is close to large urban centers, do you feel it would be appropriate to declare this area as a "marine reserve" for the benefit of present and future generations?

   Yes ☐
   No ☐
   no opinion ☐

6. Would you be in favor of setting aside many other coastal areas as "marine reserves" for the benefit of present and future Californians?

   Yes ☐
   No ☐
   no opinion ☐

7. Which of the below "marine reserve" plans would you consider to be best for all present and future generations? Check only one

   a. Let these reef areas remain as is, with no restrictions on collecting marine organisms. a ☐
   b. Only those with special permits can collect in reserves. b ☐
   c. Allow collecting and hunting of marine animals designated as abundant by the California Dept. of Fish & Game. c ☐
   d. Permit no collecting or hunting by anyone in such reserves. d ☐
   e. Other plans____________________

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The Predatory Habits of Man on Duxbury Reef

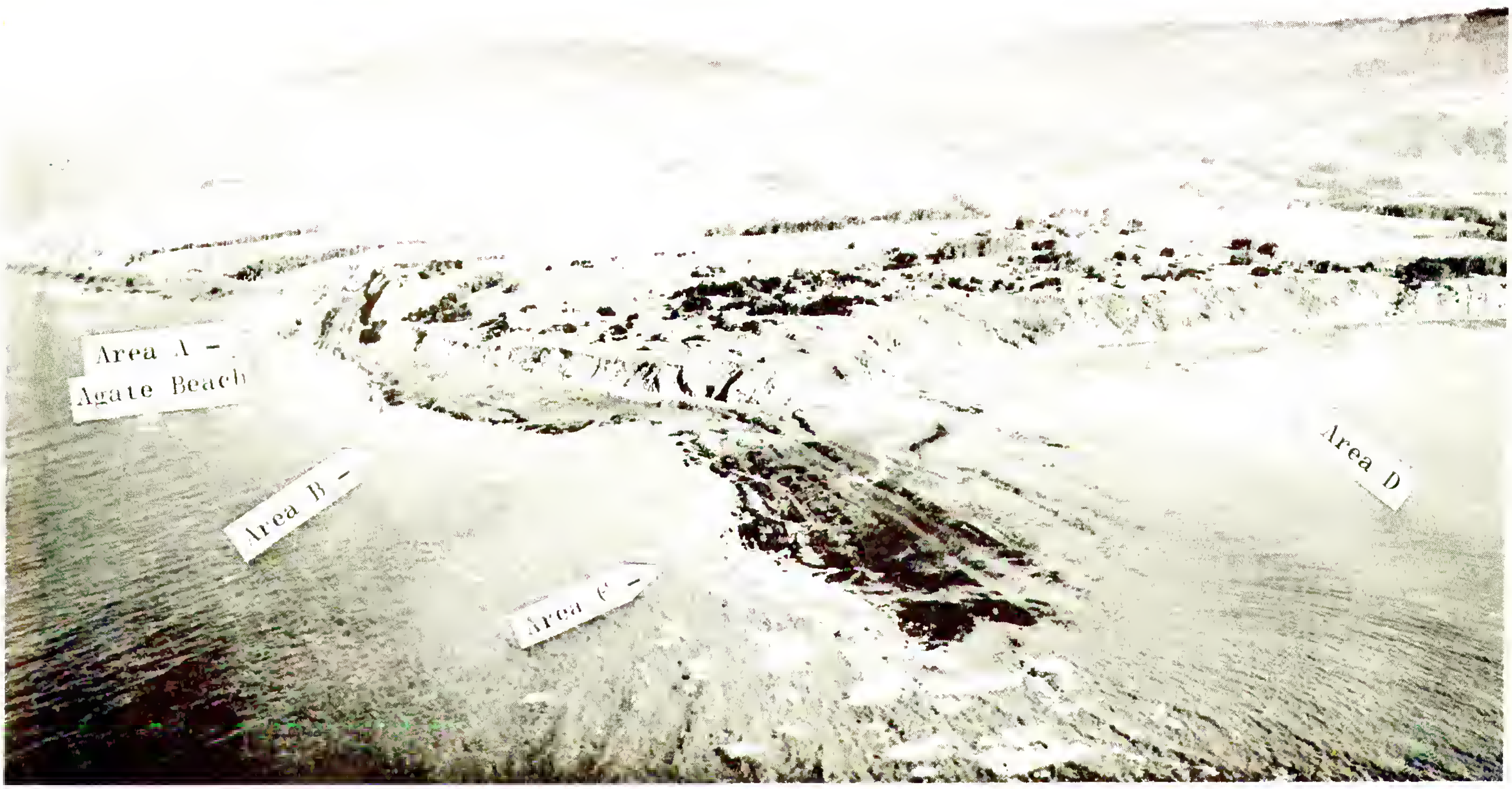

Fig. 1. Duxbury Reef in Bolinas, California, is divided into four major study areas.
Area A = Agate Beach Reef
Area B = Agate Reef Annex
Area C = Major Headland Reef
Area D = Reef Sand Flats

Fig. 2. As a hunter, man levels the reef with picks, hammers, and chisels--obtain- the boring rock clams (fig. 4). The average hunter reduces the reef level about one foot everytime he digs.

Fig. 3. Man, with his buckets, is an avid collector of marine life--gathering these trophies for home and school displays and observations.

Fig. 4. Two hunters dug into the soft shale rocks for these 300 boring Rock Clams. There is NO Fish & Game limit nor season on taking these clams.

Fig. 5. Man pries off the Chiton or Sea Cradle to use as fish bait or to collect its unique butterfly shell. In Areas A and B notice the <u>many</u> empty grooves.

Fig. 6. The Cancer Rock Crabs (female with eggs) are taken for food; and the small-swift shore crabs are hunted down in the crevices by the school collectors.

Fig. 7. Man gathers the Black Turban Snails by the sack fulls (hundreds) to eat. Others collect the snails to make necklaces, patio designs, etc.

Fig. 8. These large purple Starfish (Seastars) are collected for home and school displays. Only a remnant number remains in the outer sections of Area C. When was the last time you saw one in Areas A and B??

Fig. 9. In some areas of California, man poisons the reef to collect hundreds of seastars to sell to biological supply houses, which in turn, will sell them back to schools for display and dissections.

May 4, 1969 was the last date in which university students used poison to gather specimens (fish) from Duxbury Reef, Area B.

Fig. 10. The Abalone is basically extinct at Duxbury--only a couple remain in a remote corner of Area C. Man has achieved in eliminating the abalone from intertidal zones. throughout our 1200 miles of California coastline.

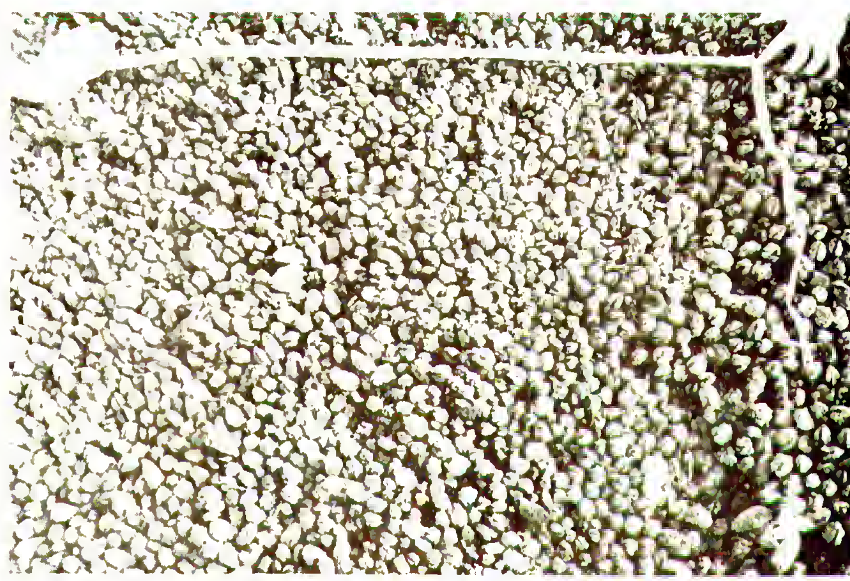

Fig. 11. Man gathers the California Mussel (above) during the winter months for food. Area C of Duxbury Reef is one of the few west coast spots where one may see vast beds of large mussels. Have you seen any mussels over 3" length in Areas A and B??

FACT: These marine animals are <u>only a sample</u> of what is nearly extinct and what remains.

QUESTION: How do these facts and photos affect you ?

OVER

Effects of Visitors on a Marine Environment

GORDON L. CHAN

Public schools for many years have instructed their students through various forms of conservation education. Yet a recent writer has felt compelled to ask: "How do we develop an ecological conscience in America? Through education, but why haven't we done so? Why aren't children taught to respect all living things?" (Donald Jackson, 1969: "Threatened America," *Life* 67 [5]: 32–43.)

The present report deals with (i) man-caused damage to the marine intertidal reefs, as exemplified by Duxbury Reef, in Marin County, California; and (ii) the effectiveness of conservation education in reducing this sort of damage.

The Problem

Most of the intertidal reefs in or near cities have been visited by the general public and by students. As a consequence, remarkable changes in the distribution of marine organisms have been noticed by ecologists. The complaint of conservationists is that these marine habitats are being stripped of their marine life.

Much of the criticism aimed at school collectors is justified. University biology teachers take their students out to collect organisms for classification. Many of these students, upon graduation, become teachers in elementary and secondary schools. They, in turn, teach their students to collect. The following advice appeared in a national publication: "Students should

Fig. 1. Two members of the general public digging into the soft shale of Duxbury Reef for clams.

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Fig. 2. Dozens of school children on Duxbury Reef during the period of conservation education.

make field trips to the seashore whenever possible to study and make collections. Several low-priced pocket field guides are available to assist in identification." (E. Winslow and A. B. Bigler, 1969: "A New Perspective on Recreational Use of the Ocean," *Undersea Technology* 10 [7]: 51–55.) There appears to be an insatiable appetite among biology teachers for exhorting their students to collect and identify specimens and to make a teaching collection for the classroom:

> Time allocation is . . . flexible . . . especially on days following field trips, when sorting, keying and preservation of specimens must be done. Students are expected to learn both the common and scientific names of the flora and fauna they investigate. All specimens must be correctly identified before they are catalogued and placed in the teaching collection. (R. B. Linsky, 1967: "Marine Biology—a Summer Enrichment Course," *Science Teacher* 34 [6]: 1–2.)

Duxbury Reef Research

The effects of collecting and hunting marine organisms for specimens and gourmet foods are evident in the following brief summary of the major findings in my study of people in a marine environment.

Duxbury Reef, in Marin County, was chosen as the intertidal urban study site because it is conveniently divided into three natural parts, which I labeled *A*, *B*, and *C* for research purposes. *A* is easily accessible to visitors; *B* is moderately accessible; and *C* is rather difficult to visit. The numbers of marine organisms in *C* are stable, but the numbers in *A* and *B* are declining under the influence of people.

Although the history of what school groups have removed from the reef was tabulated, the heart of the research was conducted during a 10-week period in the summer, when the reef receives the most visitors.

The first five weeks (30 May through 3 July 1969) were the control period—a time when people did as they pleased on the reef without the influence of conservation education (fig. 1). The second five weeks (4 July through 7 August) were the treatment period—a time when conservation education in the form of lectures, tours, signs, and handouts was provided at the reef to all visitors.

All activities of the visitors were recorded by observers, and five ecologic transects were measured in each of parts *A*, *B*, and *C* to determine if the collecting behavior of people would significantly alter the distribution of marine life. Physical measurements of oxygen, salinity, and temperature were recorded to see if these parameters had any influence on the distribution of marine organisms.

The author is director of a Sea Grant marine-technology program at the College of Marin, Kentfield, Calif. 94904. He obtained his B.A. in 1952 and his M.A. in 1953, both from Stanford University, and his Ph.D. in 1970 from the University of California. He taught biology at Sir Francis Drake High School, San Anselmo, Calif., from 1955 until he joined the College of Marin faculty, in 1964. An active SCUBA instructor, Chan last year received one of the 15 merit awards of the International Underwater Instructors Conference. He has led six diving expeditions on the Pacific coast of Baja California and in the Sea of Cortez, and he was the first marine scientist to report the discovery of giant mussels at depths of 12–30 m. His publications, chiefly in reef and lagoon ecology, include a widely publicized study of the effects of the 1971 San Francisco oil spill. At present Chan is continuing his monitoring studies on oil pollution.

Findings

The five major findings were as follows:

1. The ranges in oxygen, salinity, and temperature remained relatively constant; these factors, then, were not significant in affecting any change in the density of marine organisms. Sections of *C* showed continual stability in density of marine organisms; thus, it is unlikely that DDT and other hydrocarbons have had any effect on the density of marine organisms on Duxbury Reef.

2. The sampling data of past years (1961–69) showed a steady increase of school visitors to the reef, along with an increase in the total amounts of marine life collected. Of the 4,278 visitors in the 10-week period in 1969, at least 83% came from Marin County and the San Francisco Bay towns. The ratio of school visitors to general visitors for each sample remained essentially the same. The control period showed 2,538 visitors; of these, almost 59% were engaged in collecting activities. In the treatment period there were 1,740 visitors, and only 21.6% were collectors.

3. In both the control and the treatment period, there were more school collectors than general collectors; however, the general collectors removed a higher percentage of animals. For example, in the control period the percentage of animals collected by school visitors was 15.3%; by the general public, 84.7%. The general public gathered far more animals that were edible (clams and snails); this accounted for the large percentage difference. School collectors took small samples of each organism available.

At least 11,000 organisms were collected in the control period and only 894 in the treatment period. The average number of organisms collected dropped from 15 animals per collector in the control period to 4 animals per collector in the treatment period. Conservation education was very effective in reducing the numbers of animals removed from the reef.

4. The research on the distribution of marine organisms showed that the number of sessile animals had been reduced by collecting and that the population of mobile animals (mostly snails) fluctuated as they moved in and out of the transects. About 71% of all organisms collected were taken from part *A* (most easily accessible part of the reef), 25% from *B*, and 4% from *C* (least accessible). Overall, during the period of conservation education there was stability in the density of marine life; during the control period, instability.

5. The use of marine conservation education with school groups was highly effective in the treatment period. The behavior of the students improved: they collected fewer animals; they replaced animals picked up; they turned rocks back over; they did not tear up seaweed; and they walked carefully on the reef (fig. 2). The percentage of school visitors who collected decreased from 65.1% in the control period to 19.4% in the treatment period. During the control period students who collected averaged 4.5 animals; in the treatment period, with conservation education, the average was reduced to 2.1 animals.

Conclusions

The collecting of marine life on Duxbury Reef and, by implication, on reefs elsewhere will eventually produce a desolate environment unless conservation and marine refuge policies are enacted. This study clearly demonstrated that marine conservation education does reduce the intensity of collecting. Therefore, there must be an acceleration of conservation education in our schools—elementary school through university—and in the public media to alert people to the fact that their unrestrained collecting habits will cause irreversible damage to reefs and other places abundant in natural resources.

Phosphorus Reserves Dwindling

A report prepared by the Institute of Ecology for the 1972 U.N. Conference on the Human Environment indicates that if the current trends continue, all known reserves of phosphorus will have been used up in 60 years by a world population that will have grown to 11 billion. It also observes that world food production could support only 2 billion people if phosphate fertilizers were not available.